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# FIELD STUDIES ON THE RUST RESISTANCE OF OAT VARIETIES[1]

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IN COOPERATION WITH THE MINNESOTA AGRICULTURAL EXPERIMENT STATION

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## INTRODUCTION

The two rusts of oats, *Puccinia graminis avenae* (Pers.) Erikss. and Henn. and *P. coronata avenae* (Corda) Erikss. and Henn., do considerable damage in the United States every year, and both sometimes become destructively epidemic over extensive areas. There are two principal methods for their control—the eradication of their alternate hosts and the use of rust-resistant varieties of oats. In the Southern States both rusts develop independently of their alternate hosts, and the production of rust-resistant varieties assumes paramount importance. In the North, barberry eradication is reducing losses from stem rust somewhat, but the eradication campaign is far from completion, and there is no organized attempt to eradicate buckthorns. Therefore it is important to breed rust-resistant varieties for the Northern States also.

The importance of physiologic forms of rusts in breeding for resistance is now rather generally appreciated. Stakman, Levine, and Bailey (*18*)[3], Bailey (*2*), and Gordon (*10*) described several

[1] The investigations here reported were conducted by the Office of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Plant Pathology and Botany Division of the Minnesota Agricultural Experiment Station.

[2] The writers wish to express their appreciation for the help given by the cooperators at the different agricultural experiment stations at which the uniform rust nurseries were grown, and to H. T. Güssow, Dominion botanist, for making the necessary arrangements in eastern Canada. Thanks are due to H. B. Humphrey, principal pathologist, Office of Cereal Crops and Diseases, Bureau of Plant Industry, for advice and for help in taking notes at a number of nurseries. The writers are under obligation also to A. W. Henry and J. M. Wallace, formerly agents, Office of Cereal Crops and Diseases, and assistants in plant pathology, Minnesota Agricultural Experiment Station, for identifying some of the physiologic forms of stem rust.

[3] Reference is made by *italic* numbers in parentheses to "Literature cited," p. 34.

physiologic forms of *Puccinia graminis avenae*, while Hoerner (*12*), Popp (*16a*), and Parson (*16*) have shown that there are physiologic forms of *P. coronata avenae*. Different physiologic forms may be present in different geographic regions. Therefore a variety may be resistant in one region and susceptible in another. It is known also, in the case of *P. graminis tritici* at least, that the same forms are not necessarily present in the same region every year. Therefore a variety may behave differently with respect to rusts in the same locality in different years. It is essential, then, to learn the number, geographic distribution, and degree of mobility of physiologic forms of rusts as a basis for the most intelligent procedure in breeding. Obviously one method of obtaining this information is to grow the same varieties in many different localities for several years, with the expectation that the type and degree of rust infection will furnish preliminary information, which can then be amplified by artificial inoculations with rust collected in each locality.

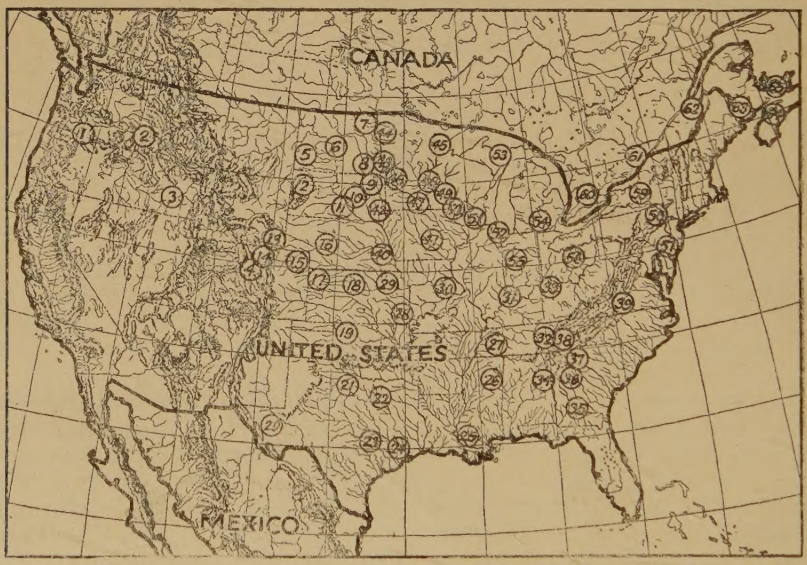


FIGURE 1.—Location of uniform oat-rust nurseries at 65 experiment stations in the United States and eastern Canada during one or more of the five years 1923 to 1927, inclusive

The investigations herein reported were initiated (1) to determine the degree of resistance of varieties of oats to stem rust and crown rust under natural environmental conditions in different parts of the United States and eastern Canada and (2) to ascertain the distribution and to determine the identity of the physiologic forms of *P. graminis avenae* responsible for the stem-rust epidemics in these regions.

## SCOPE OF EXPERIMENTS

Uniform oat nurseries, similar to those described for wheat (*6*, *13*), were first grown on a relatively modest scale in 1923. During the five years 1923 to 1927, inclusive, nurseries were grown, at one time or another, at 65 different experiment stations in the United States and eastern Canada. (Table 1 and fig. 1.) Altogether, 23 varieties

of oats were tested. (Table 2.) When the experiments were first started only 11 varieties were included in the uniform rust-nursery test at 21 experiment stations, but eventually 22 varieties were grown at 48 experiment stations.

TABLE 1.—*Location of uniform oat-rust nurseries, number of oat varieties, and names of cooperators at each of the 65 experiment stations where the rust nurseries were grown during one or more of the five years from 1923 to 1927*

| Map reference | Location | Number of varieties grown in stated years | | | | | Cooperators |
|---|---|---|---|---|---|---|---|
| | | 1923 | 1924 | 1925 | 1926 | 1927 | |
| | *Western States* | | | | | | |
| 1 | Moro, Oreg. | | | | | 22 | D. E. Stephens. |
| 2 | Moscow, Idaho | | | | | 22 | C. W. Hungerford. |
| 3 | Aberdeen, Idaho | | | | 19 | 22 | G. A. Wiebe. |
| 4 | Estes Park, Colo. | | | | | 22 | E. A. Lungren. |
| | *Northern Great Plains* | | | | | | |
| 5 | Dickinson, N. Dak. | 11 | 14 | 16 | 21 | 22 | R. W. Smith. |
| 6 | Mandan, N. Dak. | 11 | 13 | 16 | 21 | 22 | J. C. Brinsmade, jr., E. R. Ausemus. |
| 7 | Langdon, N. Dak. | 11 | 14 | | | 22 | L. R. Jorgenson, V. Sturlaugson. |
| 8 | Edgeley, N. Dak. | 11 | 14 | | | | W. E. Brentzel, O. A. Thompson. |
| 9 | Webster, S. Dak. | | | | | 22 | E. S. McFadden. |
| 10 | Redfield, S. Dak. | 11 | | 16 | | 22 | Samuel Garver. |
| 11 | Highmore, S. Dak. | | | 16 | | 22 | A. N. Hume, S. W. Sussex. |
| 12 | Newell, S. Dak. | | | 16 | 21 | 22 | Beyer Aune. |
| 13 | Archer, Wyo. | | 14 | 16 | 21 | 22 | A. L. Nelson. |
| 14 | Fort Collins, Colo. | | | 16 | 21 | 22 | E. A. Lungren. |
| 15 | Akron, Colo. | 11 | | | | 22 | F. A. Coffman, E. A. Lungren. |
| 16 | North Platte, Nebr. | | 14 | 16 | 21 | 22 | G. F. Sprague, R. W. May. |
| | *Southern Great Plains* | | | | | | |
| 17 | Colby, Kans. | | | 16 | 21 | 22 | B. F. Barnes. |
| 18 | Hays, Kans. | | | 16 | 21 | 22 | A. F. Swanson. |
| 19 | Woodward, Okla. | | | 16 | | | J. B. Sieglinger. |
| 20 | Balmorhea, Tex. | | | 16 | | | J. J. Bayles, A. H. Leidigh. |
| 21 | Chillicothe, Tex. | | | | 16 | 22 | D. L. Jones, J. R. Quinby. |
| | *Southern States* | | | | | | |
| 22 | Denton, Tex. | 10 | 14 | 16 | 16 | 22 | P. B. Dunkle, A. H. Leidigh. |
| 23 | Temple, Tex. | | 14 | 16 | 16 | | A. B. Cron, H. E. Rea. |
| 24 | College Station, Tex. | | | | 18 | 21 | R. E. Karper, P. C. Mangelsdorf. |
| 25 | Baton Rouge, La. | | | | | 22 | C. W. Edgerton, H. H. Flor. |
| 26 | Starkville, Miss. | | | 16 | 19 | 22 | D. C. Neal, J. F. O'Kelly. |
| 27 | Jackson, Tenn. | | | 16 | 21 | 22 | S. H. Essary, S. A. Robert. |
| 28 | Columbus, Kans. | | | 16 | | | J. H. Parker, I. K. Landon. |
| 29 | Manhattan, Kans. | | | 16 | 21 | 22 | C. O. Johnston, J. H. Parker. |
| 30 | Columbia, Mo. | | | 16 | 8 | 22 | L. J. Stadler. |
| 31 | Vincennes, Ind. | | | 16 | 21 | 22 | E. B. Mains, Arthur Goss. |
| 32 | Murfreesboro, Tenn. | | | 16 | | | S. H. Essary. |
| 33 | Lexington, Ky. | | | 16 | 21 | 22 | W. D. Valleau. |
| 34 | Auburn, Ala. | | | | | 22 | H. B. Tisdale. |
| 35 | Tifton, Ga. | | | | 19 | 22 | W. J. Davis. |
| 36 | Experiment, Ga. | | | 16 | | 22 | R. P. Bledsoe. |
| 37 | Athens, Ga. | 10 | | 16 | | | R. R. Childs. |
| 38 | Knoxville, Tenn. | 10 | | 16 | 21 | 22 | S. H. Essary. |
| 39 | Blacksburg, Va. | | | 16 | 21 | 22 | F. D. Fromme. |
| | *North-Central and Northeastern States* | | | | | | |
| 40 | Lincoln, Nebr. | 11 | 14 | 16 | | 22 | T. A. Kiesselbach. |
| 41 | Ames, Iowa | 11 | 14 | 16 | 21 | 22 | S. M. Dietz, L. C. Burnett. |
| 42 | Brookings, S. Dak. | 11 | 14 | 16 | 21 | 22 | A. T. Evans, Matthew Fowlds. |
| 43 | Fargo, N. Dak. | 11 | 14 | 16 | 21 | 22 | W. E. Brentzel, L. W. Boyle. |
| 44 | Crookston, Minn. | 11 | 14 | 16 | | 12 | R. S. Dunham. |
| 45 | Duluth, Minn. | 11 | 14 | 16 | 21 | 22 | M. J. Thompson, H. C. Gilbert. |
| 46 | Morris, Minn. | 11 | | 16 | | 22 | R. O. Bridgford. |
| 47 | Waseca, Minn. | 11 | 14 | | 21 | 22 | R. E. Hodgson. |
| 48 | Coon Creek, Minn. | 11 | 14 | 16 | 21 | 22 | G. E. Nesom. |
| 49 | St. Paul, Minn. | 11 | 14 | 16 | 21 | 22 | H. K. Hayes, O. S. Aamodt. |
| 50 | Red Wing, Minn. | | | | 21 | | J. T. Fulton, L. W. Melander. |

TABLE 1.—*Location of uniform oat-rust nurseries, number of oat varieties, and names of cooperators at each of the 65 experiment stations where the rust nurseries were grown during one or more of the five years from 1923 to 1927*—Continued

| Map reference | Location | Number of varieties grown in stated years | | | | | Cooperators |
|---|---|---|---|---|---|---|---|
| | | 1923 | 1924 | 1925 | 1926 | 1927 | |
| | *North-Central and Northeastern States*—Continued. | | | | | | |
| 51 | Madison, Wis. | 11 | 14 | 16 | ---- | 22 | J. G. Dickson. |
| 52 | Gurnee, Ill. | ---- | ---- | 16 | ---- | ---- | G. C. Curran. |
| 53 | Chatham, Mich. | 11 | 14 | 16 | 21 | 22 | J. E. Kotila, G. W. Putnam. |
| 54 | East Lansing, Mich. | ---- | ---- | ---- | ---- | 22 | Ray Nelson. |
| 55 | La Fayette, Ind. | ---- | ---- | 16 | 21 | 22 | E. B. Mains. |
| 56 | Columbus, Ohio | ---- | ---- | ---- | 21 | 21 | W. G. Stover, H. L. Borst. |
| 57 | Lowesville Center, Pa. | ---- | ---- | 16 | ---- | ---- | H. W. Thurston, R. S. Kirby. |
| 58 | Brooklyn, Pa. | ---- | ---- | 16 | ---- | ---- | Do. |
| 59 | Ithaca, N. Y. | ---- | ---- | ---- | 21 | 22 | H. H. Love, W. T. Craig |
| | *Eastern Canada* | | | | | | |
| 60 | Guelph, Ontario | ---- | ---- | 14 | 19 | ---- | H. T. Güssow, J. E. Howitt. |
| 61 | Ottawa, Ontario | ---- | ---- | 14 | 21 | ---- | H. T. Güssow, J. B. MacCurry. |
| 62 | St. Anne de la Pocatiere, Quebec | ---- | ---- | 14 | 21 | ---- | H. T. Güssow, H. N. Racicot. |
| 63 | Fredericton, New Brunswick | ---- | ---- | ---- | 21 | ---- | H. T. Güssow, D. J. MacLeod. |
| 64 | Kentville, Nova Scotia | ---- | ---- | 14 | 21 | ---- | H. T. Güssow, J. F. Hockey. |
| 65 | Charlottetown, Prince Edward Island. | ---- | ---- | 14 | 21 | ---- | H. T. Güssow, R. R. Hurst. |
| | Number of experiment stations each year. | 21 | 19 | 46 | 40 | 48 | |

TABLE 2.—*Varieties of oats grown in uniform rust nurseries to determine their reaction to stem rust (Puccinia graminis avenae) under field conditions during one or more of the five years from 1923 to 1927*

| Oat variety | | Number of experiment stations each year | | | | | Nursery years |
|---|---|---|---|---|---|---|---|
| Name | C. I. No. | 1923 | 1924 | 1925 | 1926 | 1927 | |
| Anthony | 2143 | ------ | ------ | 41 | 39 | 48 | 128 |
| Burt | 2043 | ------ | 19 | 46 | 40 | 47 | 152 |
| Edkin | 2330 | ------ | ------ | ------ | ------ | 47 | 47 |
| Fulghum | 708 | 21 | 19 | 46 | 39 | 47 | 172 |
| Gopher | 2027 | ------ | ------ | ------ | 36 | 47 | 83 |
| Green Mountain | 1892 | ------ | ------ | 46 | 40 | 48 | 134 |
| Hajira | 1001 | ------ | 18 | 46 | 39 | 48 | 151 |
| Iogold | 2329 | ------ | ------ | ------ | 32 | 47 | 79 |
| Iogren | 2024 | 21 | 19 | 46 | 39 | 48 | 173 |
| Iowa No. 444 | 2331 | ------ | ------ | ------ | 32 | 48 | 80 |
| Iowar | 847 | 21 | 19 | 46 | 39 | 46 | 171 |
| Joanette | 1880-1 | 18 | 19 | 46 | 40 | 48 | 171 |
| Kanota | 839 | ------ | ------ | ------ | 35 | 47 | 82 |
| Markton | 2053 | ------ | ------ | ------ | 35 | 47 | 82 |
| Minota × White Tartar (White Russian) | 2144 | ------ | ------ | 41 | 39 | 48 | 128 |
| Monarch Selection (of Etheridge) | 1879 | ------ | 19 | ------ | ------ | ------ | 19 |
| Red Rustproof | 1815 | 21 | 19 | 46 | 40 | 47 | 173 |
| Richland | 787 | 21 | 19 | 46 | 39 | 47 | 172 |
| Ruakura | 2025 | 21 | 19 | 46 | 39 | 47 | 172 |
| "Rustless selection" | 724 | 21 | 19 | 46 | 39 | 48 | 173 |
| Silvermine | 659 | 21 | 19 | 46 | 40 | 48 | 174 |
| Swedish Select | 134 | 21 | 19 | 46 | 40 | 48 | 174 |
| White Tartar | 551 | 21 | 19 | 46 | 40 | 48 | 174 |
| Total number of varieties grown each year | ------ | 11 | 14 | 16 | 21 | 22 | 3,064 |

Some of the varieties tested were known to be generally resistant to stem rust and, under certain conditions, to crown rust; others were included because of their high yielding capacity and commercial

importance; still others were essential in determining the physiologic forms of *Puccinia graminis avenae* (*2*, *18*). The varieties were grown in adjacent rod rows, the rate of seeding being 15 grams to a row. Duplicate sowings were made at each station during the first four years of the experiment, but a single sowing only was made in 1927. The rust which occurred resulted from natural infection, as no attempt was made to induce artificial epidemics.

The seed stocks of the varieties were produced in special nursery increase plots at the Aberdeen Substation, Aberdeen, Idaho,[4] under the direction of the third writer. Prior to harvesting, these plots were thoroughly rogued, and in subsequent handling of the grain every effort was made to avoid mixing the varieties.

## RESULTS OF INVESTIGATIONS

The results of the observations on the reaction of the varieties in the various nurseries are summarized in Tables 3 to 14. Tables 3 to 10

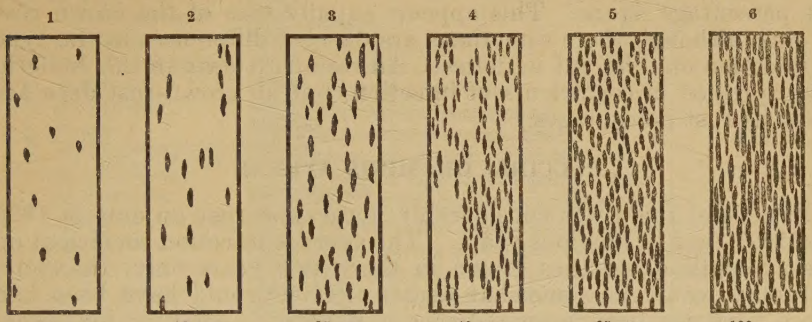


FIGURE 2.—Diagram showing six degrees of rustiness, used in estimating the percentage of rust infection on leaf or stem. The shaded spots represent rust, and the figures represent approximately the rust percentages computed on the basis of the maximum amount of surface covered by rust, as shown in the 100 per cent figure. This figure (No. 6 in the diagram) represents 37 per cent of actual surface and is arbitrarily selected as 100 per cent. Other percentages are in terms of No. 6

give the data on stem rust, and in Tables 11 to 14 the data on crown rust are presented. The rust estimates, as a rule, were made just before the plants ripened; but, for obvious reasons, this procedure could not always be followed. Most of the rust notes were taken by Levine, Stakman, and Humphrey. Some of them were taken by other staff members of the Office of Cereal Crops and Diseases engaged in the study of the epidemiology of cereal rusts. In a few instances the rust estimates were made solely by the local cooperators. In all cases where it was possible the cooperator helped in making the rust readings. In Table 1 are listed the names of the cooperators and the stations at which the nurseries were grown, together with the number of varieties grown at each station each year.

The degree of rust infection on the different varieties was determined by a comparison with the scale for estimating rust percentages (fig. 2), adopted by the Office of Cereal Crops and Diseases. This scale indicates the degree of rust but does not take into consideration differences in the type of infection. For several years, therefore, in

[4] Credit is due G. A. Wiebe, assistant agronomist, formerly in charge of cereal experiments at the Aberdeen Substation, for growing these special increase plots.

addition to recording the estimated rust percentages on the basis of Figure 2, notations were made also of the degree of susceptibility of each variety. The following symbols were used: S+ + or CS for completely susceptible, S+ or VS for very susceptible, S or MS for moderately susceptible, S− or FS for fairly susceptible, SR or IN for semiresistant or intermediate, R− or FR for fairly resistant, R or MR for moderately resistant, R+ or VR for very resistant, R+ + or ER for extremely resistant, and I or AI for apparently immune.

An attempt was made to combine these two values and give them a mathematical expression in order to show more precisely the effect of rust infection on each variety. Decimal values, ranging from 0.1 to 1.0, were arbitrarily assigned to the symbols expressing the host reaction. Multiplying these indices by the estimated rust percentages gives the coefficients of infection. Goulden and Elders (*11*) "thought best not to attempt to modify the percentage readings according to the pustule type" for the orange leaf rust of wheat, since the degree of susceptibility to leaf rust seems to be expressed accurately by the percentage figure. This appears equally true of the crown rust of oats, although there sometimes are decided differences in the type of infection on different varieties. All stem-rust data in this bulletin are expressed in coefficients of infection, but all crown-rust data are given as rust percentages.

## PUCCINIA GRAMINIS AVENAE

In general there was considerably more stem rust on oats in 1926 and 1927 than in previous years. The average infection coefficient on the susceptible varieties grown in those two years only, therefore, naturally would be somewhat higher than it would have been had these varieties been grown during the entire 5-year period, there being comparatively little rust in one year, 1925. Similarly, susceptible varieties grown only in regions where rust epidemics were especially heavy in any one year would obviously have an apparently higher average infection than equally susceptible varieties grown in the same years over the entire area or only in regions of light epidemics. Consequently, average-infection coefficients alone do not constitute an entirely reliable basis for comparison. To give a better basis of comparison, the average infection of each variety was compared with that of the Silvermine oat grown during the corresponding period in the same nurseries as the variety in question. The ratios thus obtained, expressed in percentages, and the average stem-rust coefficients are given in Table 10. The 5-year weighted average coefficients and the proportional degrees of susceptibility are shown in Figure 3.

### STEM-RUST SITUATION BY YEARS

The coefficient of stem-rust infection of each variety in each nursery, and the average infection of each variety for the given year, are shown in Tables 3 to 7. When a variety was not grown at all stations, or when, for some reason, rust estimates were not made, a dash designates the omission.

In 1923 the nurseries consisted of 11 varieties of cultivated oats and were grown at 21 experiment stations in the United States. Supplementing these uniform nurseries, a more extensive varietal

nursery was grown at St. Paul.[5] In addition to varieties and selections of cultivated oats, four species of wild oats were grown. In all, the following five species of Avena were represented: *A. brevis*, *A. nuda*, *A. sativa* (including *A. orientalis*), *A. sterilis*, and *A. strigosa*. Inasmuch as the varieties grown and the results obtained are essentially the same as those reported by Bailey (*2*, *p. 26–27*) for Canada, the results are not given in detail. The only varieties consistently and definitely resistant at St. Paul were Richland, White

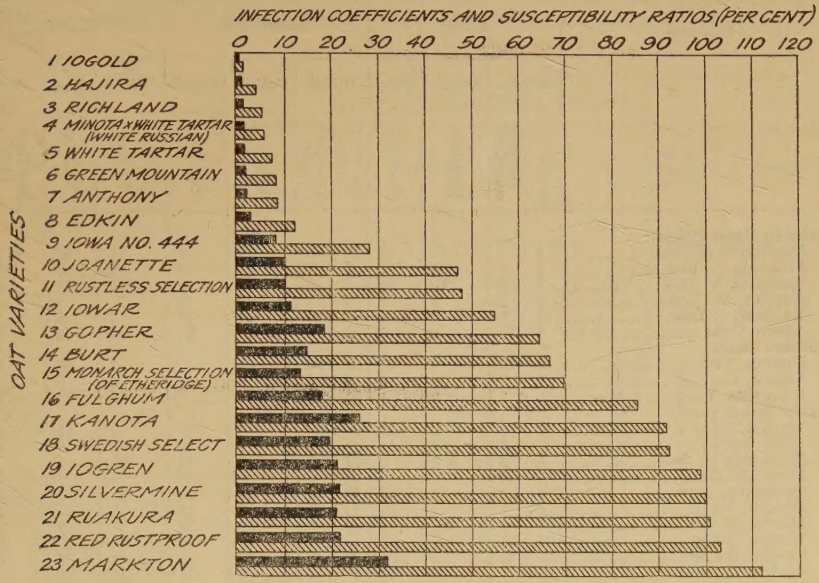


FIGURE 3.—Diagram illustrating the weighted average coefficients of infection (solid black) and the relative degree of susceptibility (cross hatching) of varieties of oats grown in uniform stem-rust nurseries during one or more of the five years from 1923 to 1927. (Numbers preceding names of varieties indicate order of relative degree of susceptibility)

Tartar, and Green Mountain. The first two (Green Mountain not being grown in the uniform nurseries in 1923) were the only varieties which proved resistant in all of the uniform-rust nurseries. Although 1923 was not considered an epidemic year, the infection coefficient, probably virtually equivalent to yield loss, was as high as 50 per cent on Ruakura at Crookston, Minn., and from 40 to 45 per cent on several other varieties in at least two other nurseries. No stem rust was found at Athens, Ga., and but very little at Knoxville, Tenn. The details for each variety in the different nurseries are presented in Table 3. Physiologic forms 1 and 2 were responsible for the epidemic in 1923.

[5] A. W. Henry made these tests in 1923 and 1924.

TABLE 3.—*Coefficients of stem-rust infection on 11 varieties of oats grown in uniform nurseries at 21 experiment stations in the United States in 1923*

[T.=Trace]

| Location | Coefficients of infection | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avena sativa | | | | | | | | A. sativa orientalis | A. byzantina | |
| | Early | | | | Midseason | | | | Late | Early | Midseason |
| | White | | Yellow | Gray | White | | Yellow | Black | White | Red | Red |
| | Iowar | "Rustless selection" | Richland | Ruakura | Silvermine | Swedish Select | Iogren | Joanette | White Tartar | Fulghum | Red Rustproof |
| Northern Great Plains: | | | | | | | | | | | |
| Dickinson, N. Dak. | 7 | 6 | T. | 11 | 23 | 30 | 23 | 18 | T. | 35 | 18 |
| Mandan, N. Dak. | 7 | 4 | T. | 12 | 7 | 9 | 16 | 16 | 0 | 18 | 20 |
| Langdon, N. Dak. | 9 | 6 | T. | 23 | 2 | 5 | 16 | 2 | 0 | 14 | 12 |
| Edgeley, N. Dak. | 7 | 4 | 0 | 6 | 5 | 2 | 5 | 10 | T. | 4 | 12 |
| Redfield, S. Dak. | 11 | 6 | 0 | 8 | 9 | 16 | 14 | 13 | 1 | 8 | 10 |
| Akron, Colo. | 4 | T. | 0 | 7 | T. | 2 | T. | T. | 0 | 2 | T. |
| Southern States: | | | | | | | | | | | |
| Denton, Tex. | 40 | 30 | 0 | 45 | 45 | 20 | 40 | ------- | 1 | 30 | 45 |
| Athens, Ga. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ------- | 0 | 0 | 0 |
| Knoxville, Tenn. | T. | 2 | 0 | 1 | T. | 0 | T. | ------- | 0 | T. | T. |
| North Central States: | | | | | | | | | | | |
| Lincoln, Nebr. | T. | 5 | 0 | 20 | 10 | 20 | 12 | 35 | 0 | 15 | 12 |
| Ames, Iowa | T. | 2 | 0 | 10 | 6 | 10 | 4 | 8 | 0 | 8 | 16 |
| Brookings, S. Dak. | 7 | 2 | 0 | 2 | 11 | 13 | 11 | 11 | T. | 4 | 8 |
| Fargo, N. Dak. | 8 | 4 | T. | 4 | 10 | 8 | 8 | 16 | 1 | 6 | 23 |
| Crookston, Minn. | 9 | 2 | 0 | 50 | 18 | 27 | 25 | 15 | T. | 25 | 30 |
| Duluth, Minn. | 6 | 4 | T. | 35 | 11 | 27 | 12 | 14 | T. | 11 | 23 |
| Morris, Minn. | T. | 4 | T. | 9 | 10 | 7 | 17 | 20 | T. | 8 | 20 |
| Waseca, Minn. | 40 | 15 | 0 | 40 | 30 | 20 | 15 | 15 | T. | 20 | 25 |
| Coon Creek, Minn. | 20 | 20 | 0 | 23 | 27 | 32 | 23 | 16 | 0 | 16 | 32 |
| St. Paul, Minn. | 12 | 4 | 0 | 10 | 10 | 12 | 8 | 18 | T. | 8 | 6 |
| Madison, Wis. | T. | T. | 0 | 18 | 4 | 10 | 6 | 9 | T. | 18 | 3 |
| Chatham, Mich. | 2 | 3 | 0 | 3 | 2 | 3 | 2 | 2 | 0 | 5 | 1 |
| Average infection coefficient | 9 | 6 | T. | 16 | 11 | 13 | 12 | 13 | T. | 12 | 15 |

The general stem-rust epidemic of 1924 was virtually of the same intensity as that of the preceding year, although it varied considerably in the different localities and areas. In all, 14 varieties of oats were grown in the nurseries in 1924, Burt, Hajira, and Monarch Selection (of Etheridge) having been added. Table 4 summarizes the data on the infection of *Puccinia graminis avenae* on these varieties grown at 19 experiment stations. The infection coefficients for the varieties grown at Temple, Tex., are averages of readings on both winter and spring sowings. Richland, Hajira, and White Tartar were resistant to stem rust at all of the stations except Temple. This suggests the presence at Temple of a virulent physiologic form of *P. graminis avenae* hitherto unknown in North America. All of the other 11 varieties proved to be at least moderately susceptible wherever enough stem rust developed to permit differentiation. Silvermine and Red Rustproof suffered most from the stem-rust attack in 1924, with Iogren and Ruakura close seconds. In 1923 the two most severely affected varieties were Ruakura and Red Rustproof. In the varietal test in 1924 at St. Paul the rust attack was light, but sufficient rust developed to indicate the degree of susceptibility of most of the varieties. Those which were resistant in 1923, namely, Richland,

White Tartar, and Green Mountain, were again resistant in 1924. No stem rust developed on Albion, Cole, Gopher, Iowar, and Nebraska No. 21, but these varieties evidently merely escaped infection because of early maturity, for they all became very heavily rusted in late sowings at Winnipeg, Manitoba (*2, p. 27*). The same physiologic forms that occurred in 1923, namely, 1 and 2, were the predominant forms in 1924 also.

TABLE 4.—*Coefficients of stem-rust infection on 14 varieties of oats grown in uniform nurseries at 19 experiment stations in the United States in 1924*

[T.=Trace]

| Location | Coefficients of infection | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avena sativa | | | | | | | | | | A. sativa orientalis | A. byzantina | | |
| | Early | | | | | Midseason | | | | | Late | Early | | Midseason |
| | White | | Yellow | | Gray | White | | Yellow | Black | | White | Red | | Red |
| | Iowar | "Rustless selection" | Hajira | Richland | Ruakura | Silvermine | Swedish Select | Iogren | Joanette | Monarch Selection (of Eth.) | White Tartar | Burt | Fulghum | Red Rustproof |
| Northern Great Plains: | | | | | | | | | | | | | | |
| Dickinson, N. Dak. | T. | T. | 0 | T. | T. | T. | T. | T. | T. | T. | T. | T. | T. | T. |
| Mandan, N. Dak. | 10 | T. | ---- | T. | 5 | 5 | T. | 1 | T. | T. | 0 | 5 | 10 | T. |
| Langdon, N. Dak. | 4 | 3 | 0 | 0 | 50 | 25 | 8 | 18 | 3 | 27 | T. | 36 | 32 | 40 |
| Edgeley, N. Dak. | 2 | T. | 0 | T. | T. | T. | T. | T. | T. | T. | T. | T. | 1 | 3 |
| Archer, Wyo. | T. | T. | 0 | 0 | T. | T. | T. | T. | 0 | 0 | 0 | T. | T. | T. |
| North Platte, Nebr. | 9 | 14 | T. | T. | 20 | 20 | 35 | 18 | 3 | 14 | 1 | 18 | 7 | 23 |
| Southern States: | | | | | | | | | | | | | | |
| Denton, Tex. | 4 | T. | T. | 0 | 5 | 7 | 7 | 10 | 27 | 5 | T. | T. | T. | 5 |
| Temple, Tex. | 7 | 8 | 8 | 16 | 6 | 6 | 7 | 5 | | 2 | 3 | 1 | 4 | 5 |
| North-Central States: | | | | | | | | | | | | | | |
| Lincoln, Nebr. | 9 | 9 | 3 | T. | 18 | 32 | 9 | 16 | 8 | 6 | 1 | 5 | 14 | 9 |
| Ames, Iowa | 18 | 4 | 0 | 0 | 45 | 23 | 7 | 36 | 1 | 12 | T. | 12 | 23 | 36 |
| Brookings, S. Dak. | 36 | 16 | T. | 0 | 16 | 60 | 45 | 50 | 23 | 45 | 1 | 12 | 32 | 36 |
| Fargo, N. Dak. | 3 | 3 | T. | T. | 4 | 10 | 6 | 4 | 2 | 10 | 1 | 6 | 6 | 8 |
| Crookston, Minn. | 3 | 4 | T. | 0 | 12 | 8 | 30 | 15 | 18 | 23 | T. | 7 | 5 | 36 |
| Duluth, Minn. | 8 | 6 | T. | T. | 16 | 40 | 18 | 35 | 8 | 23 | T. | 25 | 18 | 50 |
| Waseca, Minn. | 8 | 4 | 0 | 0 | 10 | 6 | 12 | 4 | 2 | 6 | T. | 4 | 6 | 12 |
| Coon Creek, Minn. | 8 | 9 | 0 | 0 | 4 | 7 | 8 | 6 | 1 | 8 | T. | 6 | 8 | 10 |
| St. Paul, Minn. | 10 | T. | 0 | 0 | 18 | 18 | 12 | 16 | 25 | 35 | T. | 2 | 10 | 45 |
| Madison, Wis. | 5 | 4 | 0 | T. | 24 | 16 | 15 | 16 | T. | 4 | T. | 14 | 24 | 4 |
| Chatham, Mich. | 11 | 20 | T. | T. | 70 | 85 | 41 | 75 | 5 | 36 | T. | 32 | 45 | 45 |
| Average infection coefficient | 8 | 6 | 1 | 1 | 17 | 19 | 14 | 17 | 6 | 14 | 1 | 10 | 13 | 19 |

In 1925 the nurseries were grown at 46 experiment stations in the United States and eastern Canada. (Table 5.) Hardly any stem rust appeared in the northern and southern Great Plains areas; only a trace in the Southern States, except Virginia; and but very little in the eastern Canadian Provinces. From Virginia northward in the North-Central and Northeastern States there was considerable rust. It seemed to extend gradually westward, but reached the Dakotas too late to become abundant. Purely circumstantial evidence seems to suggest that barberries in the central Eastern States were the principal source of the stem rust on oats in that year. The following

varieties and crosses of oats proved most resistant to stem rust in 1925: Hajira, Richland, White Tartar, Green Mountain, Anthony, and Minota × White Tartar (White Russian). Of the remaining 10 varieties, Red Rustproof had the highest infection coefficient for the year, but less than in either 1924 or 1923; that for Ruakura was nearly as high; and the coefficients for Silvermine, Swedish Select, and Iogren were somewhat smaller. *Puccinia graminis avenae* form 2 occurred in all nurseries in which stem rust developed, with the exception of those at Chatham, Mich., and Guelph, Ontario, where form 1 was found. The very virulent forms did not appear in 1925 in the United States, but in Canada, according to Gordon (*10, p. 463*), "a collection from Paskwegin, Saskatchewan, in 1925, yielded a form which differs in its infection capabilities from all other forms yet reported, in being able to infect heavily all differential hosts. It is considered new, and has been named physiologic form 6."

TABLE 5.—*Coefficients of stem-rust infection on 16 varieties of oats grown in uniform nurseries at 36 experiment stations in the United States and Canada in 1925*

[T.=Trace]

| Location | Coefficients of infection | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avena sativa | | | | | | | | | | | A. sativa orientalis | | A. byzantina | | |
| | Early | | | | | Midseason | | | | | | Late | | Early | Midseason | |
| | White | | Yellow | | Gray | White | | | Yellow | Black | | White | | Red | | Red |
| | Iowar | "Rustless selection" | Hajira | Richland | Ruakura | Anthony | Minota×White Tartar (White Russian) | Silvermine | Swedish Select | Iogren | Joanette | Green Mountain | White Tartar | Burt | Fulghum | Red Rustproof |
| Northern Great Plains: | | | | | | | | | | | | | | | | |
| Dickinson, N. Dak | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Mandan, N. Dak | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Redfield, S. Dak | T. | T. | 0 | 0 | 5 | 0 | 0 | 2 | 1 | 3 | 1 | T. | T. | 2 | T | 2 |
| Highmore, S. Dak | 5 | 3 | 0 | T. | 3 | T. | 0 | 5 | T. | 2 | T. | T. | 0 | 3 | 10 | T. |
| Newell, S. Dak | T. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | T. | T. |
| Archer, Wyo | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fort Collins, Colo | 0 | T. | T. | 0 | 0 | 0 | 0 | 0 | T. | T. | 2 | 0 | 0 | 0 | T. | 0 |
| North Platte, Nebr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Southern Great Plains: | | | | | | | | | | | | | | | | |
| Colby, Kans | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hays, Kans | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Woodward, Okla | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Balmorhea, Tex | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | T. | 0 | 0 |
| Southern States: | | | | | | | | | | | | | | | | |
| Denton, Tex | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | T. | 0 |
| Temple, Tex | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Starkville, Miss | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jackson, Tenn | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Columbus, Kans | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Manhattan, Kans | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | T. | T. | 0 | 0 | 0 | 0 | 0 | 0 |
| Columbia, Mo | 0 | 0 | 0 | 0 | T. | 0 | 0 | T. | 0 | T. | T. | 0 | 0 | 0 | T. | 0 |
| Vincennes, Ind | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Murfreesboro, Tenn | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lexington, Ky | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Experiment, Ga | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Athens, Ga | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Knoxville, Tenn | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Blacksburg, Va | 5 | 0 | 0 | 2 | 20 | 1 | 1 | 20 | 50 | 35 | 4 | 0 | 5 | 20 | 40 | 20 |

TABLE 5.—*Coefficients of stem-rust infection on 16 varieties of oats grown in uniform nurseries at 36 experiment stations in the United States and Canada in 1925*—Continued.

[T.=Trace]

| Location | Coefficients of infection | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avena sativa | | | | | | | | | | | A. sativa orientalis | | A. byzantina | | |
| | Early | | | | | Midseason | | | | | | Late | | Early | | Midseason |
| | White | | Yellow | | Gray | White | | | | Yellow | Black | White | | Red | | Red |
| | Iowar | "Rustless selection" | Hajira | Richland | Ruakura | Anthony | Minota × White Tartar (White Russian) | Silvermine | Swedish Select | Iogren | Joanette | Green Mountain | White Tartar | Burt | Fulghum | Red Rustproof |
| North-Central and Northeastern States: | | | | | | | | | | | | | | | | |
| Lincoln, Nebr. | T. | T. | 0 | T. | 10 | 0 | 0 | 2 | T. | 4 | 0 | T. | 0 | T. | 12 | 1 |
| Ames, Iowa | T. | 8 | 0 | 0 | 25 | T. | T. | 20 | 7 | 12 | 5 | 0 | 0 | 16 | 52 | 12 |
| Brookings, S. Dak. | 8 | 15 | T. | 0 | 50 | T. | T. | 35 | 35 | 40 | 5 | 2 | T. | 18 | 25 | 55 |
| Fargo, N. Dak. | 45 | 45 | 0 | 0 | 65 | 4 | 1 | 90 | 80 | 75 | 60 | 0 | T. | 75 | 75 | 85 |
| Crookston, Minn. | 5 | 15 | T. | 2 | 40 | T. | T. | 35 | 55 | 40 | 14 | T. | 1 | 15 | 10 | 65 |
| Duluth, Minn. | 25 | 11 | 0 | 0 | 36 | 4 | 4 | 18 | 75 | 65 | 60 | 3 | 4 | 40 | 25 | 32 |
| Morris, Minn. | 4 | 2 | 0 | 0 | 40 | T. | T. | 25 | 10 | 14 | 9 | T. | T. | 18 | 12 | 16 |
| Coon Creek, Minn. | 12 | 20 | T. | T. | 25 | 3 | 1 | 60 | 60 | 36 | 50 | 3 | 1 | 40 | 15 | 75 |
| St. Paul, Minn. | 4 | 15 | T. | T. | 20 | T. | T. | 30 | 5 | 12 | 1 | T. | T. | 20 | 40 | 2 |
| Madison, Wis. | 8 | 4 | 0 | 0 | 40 | T. | 0 | 14 | 36 | 18 | 4 | T. | T. | 10 | 14 | 75 |
| Gurnee, Ill. | 18 | 5 | 1 | 8 | 20 | 2 | 1 | 25 | 50 | 40 | 9 | T. | 2 | 15 | 20 | 45 |
| Chatham, Mich. | 23 | 14 | T. | 1 | 40 | 4 | 4 | 30 | 40 | 25 | 11 | 2 | 2 | 18 | 35 | 14 |
| La Fayette, Ind. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lowesville Center, Pa. | 25 | 30 | 3 | 4 | 65 | 15 | 10 | 45 | 25 | 30 | 15 | 10 | 10 | 60 | 40 | 45 |
| Brooklyn, Pa. | 30 | 50 | 3 | 2 | 85 | 2 | 25 | 75 | 8 | 65 | 10 | 5 | 5 | 80 | 80 | 65 |
| Eastern Canada: | | | | | | | | | | | | | | | | |
| Guelph, Ontario | T. | 5 | 0 | T. | 12 | --- | --- | 40 | 25 | 35 | 8 | T. | 2 | 15 | 15 | 25 |
| Ottawa, Ontario | 0 | 0 | 0 | 0 | 0 | --- | --- | 0 | 0 | 0 | 0 | T. | 0 | 0 | 0 | 0 |
| St. Anne de la Pocatière, Quebec | 0 | 0 | 0 | 0 | 0 | --- | --- | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kentville, Nova Scotia | 0 | T. | 0 | 0 | 0 | --- | --- | T. | T. | T. | 0 | 0 | 0 | 0 | 0 | T. |
| Charlottetown, Prince Edward Island | 0 | 0 | 0 | 0 | 0 | --- | --- | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Average infection coefficient | 5 | 5 | T. | T. | 13 | 1 | 1 | 12 | 12 | 12 | 6 | 1 | 1 | 10 | 11 | 14 |

Five new varieties were added in 1926, bringing the total up to 21. Stem-rust notes were taken at 40 different stations in the United States and eastern Canada. (Table 6.) Although in Texas there was heavy stem-rust infection of oats at College Station and Denton, there was very little at Temple, and only a trace at Chillicothe. In the three nurseries in Kansas and northward, the degree of stem rust on oats increased, reaching a maximum at Ames, Iowa, and Fargo, N. Dak. In western North Dakota, however, there was very little stem rust. The most resistant varieties in 1926 were practically identical with those resistant in previous years. They were as follows, in the order of their resistance: Hajira, Iogold, Minota × White Tartar (White Russian), Anthony, Richland, Green Mountain, and White Tartar. The average infection coefficients for these varieties ranged from 0.7 to 3.5. Of the two new varieties added, Iogold and Iowa No. 444, the former proved to be extremely resistant. The average infection coefficient of Iogold was only 0.6. The reaction of this variety to the known physiologic forms of *Puccinia graminis*

*avenae* is similar to that of Richland and Hajira. Iowa No. 444, like Joanette, appears to be genetically impure, as there was considerable variation in the degree and type of infection even on individual plants in different nurseries. The most susceptible variety in 1926 was Markton, but Silvermine, Ruakura, and Iogren were almost as susceptible. The detailed results for all varieties in all of the nurseries are summarized in Table 6. Physiologic form 2 of *P. graminis avenae* again occurred in all of the nurseries and probably was principally responsible for the rust epidemic.

TABLE 6.—*Coefficients of stem-rust infection on 21 varieties of oats grown in uniform nurseries at 40 experiment stations in the United States and eastern Canada in 1926*

[T. = Trace]

| Location | Coefficients of infection | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avena sativa | | | | | | | | | | | | | | | A. sativa orientalis | A. byzantina | | | | |
| | Early | | | | | | | | Midseason | | | | | | | Late | Early | | | | Midseason |
| | White | | | | Yellow | | | Gray | White | | | | Yellow | | Black | White | Red | | | | Red |
| | Gopher | Iowa No. 444 | Iowar | "Rustless selection" | Hajira | Iogold | Richland | Ruakura | Anthony | Minota × White Tartar | Silvermine | Swedish Select | Iogren | Markton | Joanette | Green Mountain | White Tartar | Burt | Fulghum | Kanota | Red Rustproof |
| Western States: | | | | | | | | | | | | | | | | | | | | | |
| Aberdeen, Idaho | T. | --- | T. | 0 | 0 | --- | 0 | T. | T. | T. | 0 | T. | T. | T. | T. | T. | 0 | 0 | 0 | 0 | 0 |
| Northern Great Plains: | | | | | | | | | | | | | | | | | | | | | |
| Dickinson, N. Dak. | T. | 0 | T. | T. | 0 | 0 | 0 | T. | 0 | T. | T. | T. | T. | T. | T. | 0 | T. | T. | 0 | 0 | T. |
| Mandan, N. Dak. | 25 | 8 | 13 | 13 | 0 | T. | 0 | 35 | 0 | 0 | 15 | 15 | 20 | 8 | 18 | T. | 2 | 25 | 25 | 30 | 18 |
| Newell, S. Dak. | 3 | T. | 3 | 3 | 0 | T. | T. | 25 | 0 | 0 | 5 | 20 | 60 | 60 | 0 | T. | T. | 3 | 8 | 12 | 2 |
| Archer, Wyo. | T. | 10 | T. | T. | 0 | 0 | T. | T. | T. | 0 | T. | T. | T. | 9 | 0 | 0 | 0 | T. | T. | T. | T. |
| Fort Collins, Colo. | 9 | 4 | 5 | 5 | T. | 0 | 0 | 25 | T. | 0 | 11 | 7 | 4 | 35 | 4 | 0 | T. | 30 | 40 | 50 | 16 |
| North Platte, Nebr. | 8 | 2 | 4 | 12 | T. | 0 | 0 | 20 | T. | 1 | 18 | 15 | 10 | 15 | 18 | T. | 1 | 5 | 25 | 20 | 7 |
| Southern Great Plains: | | | | | | | | | | | | | | | | | | | | | |
| Colby, Kans. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | T. | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hays, Kans. | 0 | 0 | 5 | 3 | 0 | 0 | 0 | 7 | 0 | 0 | 5 | 1 | 3 | 3 | 0 | 0 | 0 | 0 | 7 | 4 | 0 |
| Chillicothe, Tex. | --- | --- | T. | T. | T. | --- | T. | T. | T. | T. | T. | T. | T. | --- | T. | T. | T. | T. | T. | --- | T. |
| Southern States: | | | | | | | | | | | | | | | | | | | | | |
| Denton, Tex. | --- | --- | 45 | 30 | T. | --- | T. | 40 | 3 | 3 | 68 | 80 | 59 | --- | 36 | T. | T. | 40 | 25 | --- | 70 |
| Temple, Tex. | --- | --- | 2 | 1 | 0 | --- | 0 | 1 | 1 | T. | 3 | 4 | 10 | --- | 1 | 2 | 3 | 2 | 1 | --- | 4 |
| College Station, Tex. | 65 | 18 | 65 | 70 | 2 | 1 | 65 | 75 | 9 | T. | 72 | 80 | 90 | --- | 35 | 18 | 45 | 70 | --- | --- | 72 |
| Starkville, Miss. | 1 | --- | 0 | 0 | 0 | --- | 0 | 2 | 0 | 0 | 1 | 3 | 2 | 2 | 0 | 0 | 1 | 1 | 0 | 2 | 5 |
| Jackson, Tenn. | 5 | 0 | 0 | 3 | T. | 0 | 3 | 4 | 2 | T. | 0 | 1 | 20 | 2 | 0 | 2 | 16 | 0 | 3 | 3 | 4 |
| Manhattan, Kans. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Columbia, Mo. | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 50 | 50 | --- | --- | 30 | 1 | 1 | 50 | 45 | --- | 65 |
| Vincennes, Ind. | 1 | 0 | 5 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 2 | 0 | 10 | 9 | 1 | 0 | 0 | 3 | 2 | 10 | 3 |
| Lexington, Ky. | 10 | 18 | 10 | 20 | 1 | T. | 0 | 25 | 1 | 1 | 50 | 18 | 25 | 35 | 14 | T. | 1 | 12 | 20 | 25 | 18 |
| Tifton, Ga. | 4 | --- | 1 | 0 | 0 | --- | 2 | 2 | 1 | 0 | 2 | 3 | 2 | 2 | 0 | 0 | 0 | 16 | 4 | 1 | 2 |
| Knoxville, Tenn. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Blacksburg, Va. | 2 | 0 | 2 | 5 | 0 | 0 | 0 | 2 | T. | T. | 5 | 4 | 4 | 5 | T. | T. | 1 | 4 | 2 | 7 | 7 |

TABLE 6.—*Coefficients of stem-rust infection on 21 varieties of oats grown in uniform nurseries at 40 experiment stations in the United States and eastern Canada in 1926*—Continued.

[T.=Trace]

| Location | Coefficients of infection | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avena sativa | | | | | | | | | | | | | | | A. sativa orientalis | A. byzantina | | | | |
| | Early | | | | | | | | Midseason | | | | | | | Late | Early | | | Midseason | |
| | White | | | | Yellow | | | Gray | White | | | | Yellow | | Black | White | Red | | | Red | |
| | Gopher | Iowa No. 444 | Iowar | "Rustless selection" | Hajira | Iogold | Richland | Ruakura | Anthony | Minota × White Tartar | Silvermine | Swedish Select | Iogron | Markton | Joanette | Green Mountain | White Tartar | Burt | Fulghum | Kanota | Red Rustproof |
| North-Central and Northeastern States: | | | | | | | | | | | | | | | | | | | | | |
| Ames, Iowa | 90 | 3 | 75 | 60 | 2 | 2 | T. | 90 | 2 | 1 | 90 | 85 | 95 | 85 | 41 | 1 | 2 | 45 | 36 | 85 | 85 |
| Brookings, S. Dak. | 69 | 42 | 68 | 56 | 9 | 6 | 9 | 70 | 20 | 21 | 75 | 82 | 75 | 68 | 77 | 20 | 23 | 68 | 68 | 68 | 80 |
| Fargo, N. Dak. | 90 | 50 | 90 | 85 | 3 | 1 | 8 | 85 | 8 | 8 | 95 | 90 | 90 | 95 | 75 | 8 | 8 | 36 | 90 | 90 | 90 |
| Duluth, Minn. | 9 | 14 | 14 | 9 | 0 | 0 | 0 | 41 | 1 | 2 | 35 | 18 | 14 | 50 | 14 | 2 | 2 | 32 | 14 | 18 | 65 |
| Waseca, Minn. | 30 | 7 | 30 | 25 | T. | 0 | T. | 60 | 1 | 1 | 70 | 65 | 60 | 35 | 30 | 2 | 5 | 14 | 45 | 65 | 95 |
| Coon Creek, Minn. | 35 | 30 | 25 | 36 | 1 | T. | T. | 80 | 1 | 1 | 75 | 45 | 50 | 95 | 23 | 1 | 1 | 65 | 85 | 90 | 75 |
| St. Paul, Minn. | 4 | 0 | 4 | 7 | 0 | 0 | 0 | 12 | 0 | 0 | 2 | 15 | 10 | 25 | 4 | T. | 0 | 4 | 6 | 4 | 9 |
| Red Wing, Minn. | 5 | 0 | 9 | 9 | T. | 0 | 0 | 45 | T. | T. | 18 | 18 | 25 | 65 | 11 | T. | T. | 15 | 18 | 18 | 30 |
| Chatham, Mich. | 36 | 1 | 32 | 27 | 1 | 1 | 2 | 50 | 3 | 3 | 95 | 65 | 80 | 45 | 70 | 1 | 1 | 18 | 23 | 41 | 75 |
| La Fayette, Ind. | 4 | 3 | 9 | 9 | T. | 0 | T. | 38 | T. | T. | 30 | 18 | 38 | 45 | 2 | 0 | T. | 38 | 45 | 45 | 30 |
| Columbus, Ohio | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Ithaca, N. Y. | 12 | 3 | 5 | 6 | 2 | 5 | T. | 41 | 2 | 2 | 58 | 41 | 41 | 68 | 20 | 2 | 2 | 12 | 45 | 72 | 72 |
| Eastern Canada: | | | | | | | | | | | | | | | | | | | | | |
| Guelph, Ontario | 63 | --- | 18 | 20 | 3 | --- | 1 | 90 | 36 | 21 | 95 | 95 | 85 | 95 | 28 | 36 | 21 | 41 | 68 | 90 | 90 |
| Ottawa, Ontario | 25 | T. | 25 | 11 | 0 | 0 | T. | 54 | T. | T. | 41 | 32 | 49 | 45 | 1 | T. | T. | 27 | 55 | 35 | 6 |
| St. Anne de la Pocatière, Quebec | 68 | 15 | 54 | 63 | T. | T. | T. | 78 | 5 | T. | 68 | 59 | 72 | 81 | 9 | 2 | T. | 72 | 72 | 81 | 36 |
| Fredericton, New Brunswick | 5 | T. | T. | T. | 0 | T. | T. | 32 | T. | 0 | 8 | 14 | 14 | 23 | 6 | T. | T. | 6 | 23 | 18 | T. |
| Kentville, Nova Scotia | 16 | T. | 6 | 25 | T. | 0 | 0 | 80 | 0 | 0 | 80 | 0 | 80 | T. | 0 | 0 | 0 | 0 | 32 | 23 | 8 |
| Charlottetown, Prince Edward Island | T. | 0 | T. | T. | 0 | T. | 0 | T. | 0 | 0 | T. | T. | T. | T. | 0 | 0 | 0 | T. | T. | T. | 0 |
| Average infection coefficient | 19 | 7 | 16 | 16 | 1 | 1 | 2 | 31 | 2 | 2 | 31 | 26 | 31 | 32 | 14 | 3 | 4 | 19 | 24 | 29 | 28 |

Rust conditions in 1927 were not essentially different from those in 1926, although stem rust was much heavier in 1927 in the northern Great Plains and in the States bordering on the Great Lakes, and much lighter in the southern Great Plains and on the Atlantic seaboard. The different varieties tested, as may be noted from Table 7, behaved as a whole in very much the same manner as in previous years. The average coefficient of infection for the respective varieties in 1927 was in many cases strikingly similar to that of 1926, although the physiologic forms isolated were slightly different in the two years.

*Puccinia graminis avenae* form 2 was common and almost omnipresent in 1927, as it was also in 1926. Form 1 was isolated from a number of nurseries in 1926, but it was not found at all in the United States in 1927. Form 5 was found in 1927 at Starkville, Miss., and at Fargo, N. Dak. Form 5, however, is not greatly different from form 1. The only difference is the effect on "Joanette strain" and "Strain 703," both of which are very resistant to form 1 and indeterminate to form 5. There may have been an error in the sowing order in the Fort Collins, Colo., nursery in 1927. Elsewhere, if there was a distinct difference in the stem-rust infection on Richland and Edkin, the latter was the more heavily infected. But at Fort Collins, the infection coefficient for Richland was 41 and only a trace for Edkin. Richland normally reacts like Hajira and Iogold, and these two had but a trace or no rust at all at Fort Collins. It is therefore fairly safe to assume an error in labeling.

TABLE 7.—*Coefficients of stem-rust infection on 22 varieties of oats grown in uniform nurseries at 48 experiment stations in the United States in 1927*

[T. = Trace]

| Location | Coefficients of infection | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avena sativa | | | | | | | | | | | | | | | | A. sativa orientalis | A. byzantina | | | | |
| | Early | | | | | | | | | Midseason | | | | | | | Late | Early | | | Mid-season | |
| | White | | | | Yellow | | | | Gray | White | | | Yellow | | Black | | White | Red | | | Red | |
| | Gopher | Iowa No. 444 | Iowar | "Rustless selection" | Edkin | Hajira | Iogold | Richland | Ruakura | Anthony | Minota × White Tartar (White Russian) | Silvermine | Swedish Select | Iogren | Markton | Joanette | Green Mountain | White Tartar | Burt | Fulghum | Kanota | Red Rustproof |
| Western States: | | | | | | | | | | | | | | | | | | | | | | |
| Moro, Oreg. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Moscow, Idaho | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Aberdeen, Idaho | 3 | 2 | 3 | 10 | T. | 0 | 0 | 0 | 20 | 0 | 0 | 10 | 5 | 10 | 30 | 5 | 0 | 0 | 3 | 5 | 20 | 10 |
| Estes Park, Colo. | 0 | 0 | 0 | T. | 0 | 36 | 0 | 0 | 36 | 0 | 0 | 5 | 4 | 4 | T. | 0 | 20 | 0 | 4 | 5 | T. | 0 |
| Northern Great Plains: | | | | | | | | | | | | | | | | | | | | | | |
| Dickinson, N. Dak. | 20 | 2 | 8 | 8 | T. | T. | T. | T. | 20 | T. | T. | 4 | 12 | 11 | 12 | 4 | T. | T. | 18 | 32 | 21 | 16 |
| Mandan, N. Dak. | 8 | T. | 16 | 16 | 2 | T. | T. | T. | 76 | 2 | T. | 48 | 52 | 56 | 72 | 14 | 5 | 3 | 48 | 68 | 60 | 72 |
| Langdon, N. Dak. | 11 | 1 | 27 | 10 | T. | 0 | 0 | T. | 9 | 1 | T. | 15 | 11 | 35 | 13 | 6 | 1 | 1 | 5 | 4 | 2 | 45 |
| Webster, S. Dak. | 14 | 3 | 18 | 4 | 0 | 0 | 0 | 0 | 11 | 1 | 1 | 23 | 7 | 23 | 11 | 8 | 1 | 1 | 9 | 9 | 9 | 27 |
| Redfield, S. Dak. | 16 | 1 | 4 | 4 | 0 | 0 | 2 | 0 | 12 | 1 | 2 | 24 | 20 | 32 | 28 | 8 | 1 | 2 | 16 | 24 | 32 | 8 |
| Highmore, S. Dak. | 8 | 16 | 8 | 8 | T. | T. | 1 | 0 | 20 | 1 | T. | 32 | 32 | 40 | 48 | 16 | 2 | 4 | 32 | 48 | 52 | 56 |
| Newell, S. Dak. | 35 | 3 | 40 | 40 | 0 | 0 | 0 | 0 | 25 | 0 | 0 | 25 | 25 | 25 | 75 | 1 | 0 | 0 | 45 | 45 | 30 | 10 |
| Archer, Wyo. | 36 | 4 | 23 | 23 | 36 | 7 | 0 | 0 | 36 | 36 | 0 | 65 | 36 | 3 | 65 | 28 | 0 | 0 | 36 | 65 | 36 | 17 |
| Fort Collins, Colo. | 90 | 65 | 58 | 100 | T. | T. | 0 | 41 | 65 | 7 | T. | 41 | 58 | 58 | 100 | 52 | 5 | 17 | 58 | 58 | 100 | 100 |
| Akron, Colo. | 45 | 31 | 45 | 58 | 41 | 0 | 2 | T. | 75 | 8 | 0 | 75 | 75 | 75 | 100 | 20 | 7 | 20 | 57 | 75 | 75 | 50 |
| North Platte, Nebr. | T. | 0 | T. | T. | T. | 0 | 0 | 0 | T. | T. | T. | T. | 1 | T. | 1 | T. | T. | T. | 1 | 1 | 1 | T. |
| Southern Great Plains: | | | | | | | | | | | | | | | | | | | | | | |
| Colby, Kans. | T. | 0 | T. | T. | 0 | 0 | 0 | 0 | 10 | T. | 0 | T. | T. | 1 | 5 | T. | T. | T. | 5 | 10 | 10 | 2 |
| Hays, Kans. | 10 | T. | 10 | 1 | 0 | 0 | 0 | 0 | 4 | T. | 0 | 1 | 4 | T. | 15 | 2 | T. | T. | 4 | 8 | 4 | 1 |
| Chillicothe, Tex. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

TABLE 7.—*Coefficients of stem-rust infection on 22 varieties of oats grown in uniform nurseries at 48 experiment stations in the United States in 1927*—Continued

[T.=Trace]

| Location | Coefficients of infection | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avena sativa | | | | | | | | | | | | | | | A. sativa orientalis | A. byzantina | | | | |
| | Early | | | | | | | | | Midseason | | | | | | Late | Early | | | Midseason | |
| | White | | | | Yellow | | | | Gray | White | | | Yellow | Black | | White | Red | | | Red | |
| | Gopher | Iowa No. 444 | Iowar | "Rustless selection" | Edkin | Hajira | Iogold | Richland | Ruakura | Anthony | Minota × White Tartar (White Russian) | Silvermine | Swedish Select | Iogren | Markton | Joanette | Green Mountain | White Tartar | Burt | Fulghum | Kanota | Red Rustproof |
| Southern States: | | | | | | | | | | | | | | | | | | | | | |
| Denton, Tex. | 0 | 0 | 1 | 0 | T. | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | T. | 0 | 0 | 0 | 0 | 2 | 0 | T. |
| College Station, Tex. | 16 | 4 | 4 | 4 | T. | 1 | 0 | T. | 8 | T. | T. | 8 | 10 | 8 | --- | 4 | T. | T. | 20 | 4 | 4 | 16 |
| Baton Rouge, La. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Starkville, Miss. | 4 | 9 | 4 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 8 | 4 | 12 | 4 | 0 | 0 | 0 | 15 | 5 | 25 | 4 |
| Jackson, Tenn. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Manhattan, Kans. | 2 | 4 | T. | 5 | 2 | T. | 0 | T. | 4 | T. | T. | 4 | 4 | 4 | 4 | 0 | 1 | T. | 5 | 10 | 10 | 4 |
| Columbia, Mo. | 24 | 20 | 20 | 12 | 16 | T. | T. | 24 | 60 | 2 | T. | 40 | 32 | 60 | 32 | 2 | 1 | 1 | 32 | 32 | 24 | 18 |
| Vincennes, Ind. | 9 | 15 | 9 | 5 | 0 | 0 | 0 | 0 | 12 | T. | T. | 5 | 4 | 20 | 7 | 2 | 1 | 1 | 4 | 2 | 7 | 4 |
| Lexington, Ky. | T. | T. | 4 | T. | 0 | 0 | 0 | 0 | 7 | 0 | T. | 12 | 4 | 2 | 3 | 1 | 0 | T. | T. | 1 | 1 | 15 |
| Auburn, Ala. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tifton, Ga. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Experiment, Ga. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Knoxville, Tenn. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Blacksburg, Va. | 2 | 3 | 12 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 12 | 12 | 12 | 12 | 5 | 1 | 1 | 12 | 12 | 12 | 12 |
| North-Central and Northeastern States: | | | | | | | | | | | | | | | | | | | | | |
| Lincoln, Nebr. | 3 | 16 | 1 | 8 | T. | T. | T. | T. | 16 | T. | 12 | 8 | 10 | 20 | 20 | 4 | 0 | T. | 20 | 20 | 20 | 20 |
| Ames, Iowa | 20 | T. | 20 | 32 | 15 | T. | T. | 0 | 54 | 10 | 2 | 60 | 54 | 45 | 50 | 35 | 4 | 3 | 20 | 23 | 24 | 90 |
| Brookings, S. Dak. | 20 | 24 | 52 | 20 | T. | T. | T. | T. | 25 | T. | T. | 52 | 40 | 60 | 50 | 32 | T. | T. | 20 | 35 | 25 | 68 |
| Fargo, N. Dak. | 4 | 12 | 12 | 12 | 0 | 0 | 0 | 0 | 40 | 5 | 1 | 42 | 44 | 60 | 34 | 44 | 1 | 2 | 8 | 4 | 4 | 32 |
| Crookston, Minn. | --- | 56 | --- | 5 | --- | 2 | --- | --- | --- | 12 | 6 | 70 | 95 | 64 | 100 | 15 | 12 | 5 | --- | --- | --- | --- |
| Duluth, Minn. | 40 | 58 | 65 | 23 | T. | 1 | 2 | T. | 41 | 2 | 1 | 80 | 85 | 41 | 32 | 40 | 1 | 2 | 32 | 27 | 36 | 75 |
| Morris, Minn. | 65 | 8 | 70 | 21 | 3 | T. | T. | 2 | 30 | 24 | 20 | 85 | 75 | 80 | 75 | 52 | 24 | 28 | 15 | 85 | 90 | 86 |
| Waseca, Minn. | 30 | T. | 15 | 8 | 25 | T. | T. | 0 | 80 | T. | T. | 50 | 70 | 65 | 75 | T. | 0 | 0 | 58 | 60 | 60 | 35 |
| Coon Creek, Minn. | 30 | 4 | 20 | 25 | 0 | 0 | 0 | 0 | 60 | 15 | 6 | 50 | 45 | 45 | 90 | 19 | 13 | 3 | 5 | 45 | 30 | 80 |
| St. Paul, Minn. | 30 | 9 | 35 | 30 | 0 | 0 | 0 | 0 | 45 | 1 | 1 | 60 | 85 | 65 | 45 | 18 | 2 | 2 | 35 | 45 | 30 | 75 |
| Madison, Wis. | 95 | 30 | 85 | 75 | 1 | 1 | T. | T. | 98 | 3 | 2 | 100 | 98 | 100 | 90 | 15 | 2 | 1 | 95 | 98 | 95 | 65 |
| Chatham, Mich. | 40 | 4 | 10 | 15 | T. | 40 | T. | T. | 8 | 4 | 4 | 75 | 75 | 50 | 75 | 32 | 20 | 6 | 50 | 25 | 25 | 75 |
| East Lansing, Mich. | 65 | 15 | 50 | 70 | T. | T. | 1 | T. | 95 | 6 | 5 | 85 | 90 | 85 | 90 | 70 | 3 | 3 | 32 | 75 | 75 | 98 |
| La Fayette, Ind. | 40 | 3 | 45 | 18 | 5 | 1 | T. | 3 | 18 | 1 | T. | 20 | 15 | 25 | 25 | 3 | 2 | T. | 23 | 23 | 18 | 15 |
| Columbus, Ohio | 0 | 4 | --- | 10 | T. | 1 | 0 | T. | 25 | 1 | T. | 10 | 10 | 10 | 10 | 3 | 0 | 1 | 10 | 20 | 20 | 4 |
| Ithaca, N. Y. | T. | T. | T. | T. | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 6 | 2 | 2 | 2 | T. | 0 | 0 | T. | 3 | 2 | 15 |
| Average infection coefficient | 18 | 9 | 17 | 14 | 3 | 2 | T. | 2 | 25 | 3 | 1 | 27 | 27 | 28 | 32 | 12 | 3 | 2 | 18 | 24 | 22 | 28 |

## RESULTS BY AREAS

In such a vast territory as the one under discussion, pronounced variation in the severity of the rust epidemic during a given season would be expected in the different areas comprising this territory. In 1925, for example, there was only a bare trace of stem rust in the nurseries of the Great Plains area, while the severity of rust in the

nurseries of the North-Central and Northeastern States averaged as high as 18 per cent. Of course, there also is a seasonal difference in the intensity of a rust epidemic in the same geographic area in different years. Thus, in the northern Great Plains in 1925, stem rust averaged less than 1 per cent, while in 1927 there was an average of 20 per cent in the same area. In eastern Canada, in 1925, the average was only 3 per cent, while in 1926 it amounted to 22 per cent, even though several highly resistant varieties were added to the nurseries in the latter year, which naturally lowered the average.

Obviously, then, the average yearly infection, even for the most susceptible variety, must necessarily be rather low where the entire area is taken into consideration. The average infection coefficient for the variety Markton for the whole 5-year period did not exceed 32 per cent; whereas the same variety in the northern Great Plains averaged 38 per cent, and in the North-Central and Northeastern States the average was as high as 55 per cent. Naturally, where and when the rust epidemics are the most severe, the differences between the resistant and susceptible varieties are most pronounced and the results most significant.

Table 8 summarizes the reaction to stem rust of the different varieties grown in the 60 or more nurseries, by individual years and by geographic areas. In none of these areas was the severity of the rust epidemics the same or nearly the same each year. In some regions, the yearly variation was greater than in others and the average severity higher for the period under review. These two features, however, were in no sense corollary. The greatest range of seasonal variation occurred in the northern Great Plains area, the annual intensity limits being trace and 20 per cent, respectively. The western area, perhaps, is the least variable area in so far as oat stem-rust epidemics are concerned, although uniform oat-rust nurseries there have been maintained for only two years. Two years in some areas, however, as for instance eastern Canada, may be quite sufficient to bring out the extent of seasonal variations. It is significant that even under the most trying rust conditions, the varieties that had the lowest average annual infection coefficients in the experimental territory as a whole also were the most resistant varieties in the separate areas. Those regions in which the presence of particularly virulent physiologic forms was at times suspected constituted exceptions. On the average, the oats of the western area, the southern Great Plains, and the Southern States do not seem to suffer frequently or very greatly from stem-rust epidemics. In the North-Central and Northeastern States, however, these epidemics are more regular and of considerably greater intensity.

TABLE 8.—*Stem-rust coefficient on 23 varieties of oats grown in different sections of the United States and eastern Canada during one or more of the five years from 1923 to 1927*

[T.=Trace]

| Area and year | Coefficients of infection | | | | | | | | | | | | | | | | | | | | | | | | Severity of rust epidemic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avena sativa | | | | | | | | | | | | | | | | | | A. sativa orientalis | | A. byzantina | | | | |
| | Early | | | | | | | | Midseason | | | | | | | | | | Late | | Early | | | Midseason | |
| | White | | | | Yellow | | | Gray | White | | | | Yellow | | Black | | | | White | | Red | | | Red | |
| | Gopher | Iowa No. 444 | Iowar | "Rustless selection" | Edkin | Hajira | Iogold | Richland | Kunkura | Anthony | Minota × White Tartar (White Russian) | Silvermine | Swedish Select | Iogren | Markton | Joanette | Monarch Selection (of Etheridge) | Green Mountain | White Tartar | Burt | Fulghum | Kanota | Red Rustproof | |
| Western States: | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1926 | T. | | T. | 0 | | 0 | | 0 | T. | T. | T. | 0 | T. | T. | T. | | | T. | 0 | 0 | 0 | 0 | 0 | T. |
| 1927 | 1 | 1 | 1 | 3 | T. | 9 | 0 | 0 | 14 | 0 | 0 | 4 | 2 | 4 | 8 | 1 | | 5 | 0 | 2 | 2 | 5 | 2 | 3 |
| Average | 1 | 1 | 1 | 2 | T. | 7 | 0 | 0 | 11 | T. | T. | 3 | 2 | 3 | 6 | 1 | | 4 | 0 | 1 | 2 | 4 | 2 | 2 |
| Northern Great Plains: | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1923 | | | 8 | 4 | | | | T. | 11 | | | 8 | 11 | 12 | | 10 | | | T. | | 14 | | 12 | 8 |
| 1924 | | | 4 | 3 | | T. | | T. | 13 | | | 8 | 7 | 6 | | 1 | 7 | | T. | 10 | 8 | | 11 | 6 |
| 1925 | | | 1 | T. | | T. | | T. | 1 | T. | T. | 1 | T. | 1 | | T. | | T. | T. | 1 | 1 | | T. | T. |
| 1926 | 8 | 4 | 4 | 6 | | T. | T. | T. | 18 | T. | T. | 8 | 10 | 16 | 21 | 7 | | T. | 1 | 11 | 16 | 19 | 7 | 7 |
| 1927 | 26 | 12 | 23 | 25 | 7 | 1 | 1 | 4 | 32 | 5 | T. | 32 | 30 | 33 | 48 | 14 | | 2 | 4 | 30 | 39 | 38 | 37 | 20 |
| Average | 19 | 9 | 9 | 10 | 7 | T. | T. | 1 | 16 | 2 | T. | 14 | 13 | 15 | 38 | 7 | 7 | 1 | 2 | 15 | 18 | 31 | 16 | 11 |
| Southern Great Plains: | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1925 | | | 0 | 0 | | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | | 0 | 0 | T. | 0 | | 0 | 0 |
| 1926 | 0 | 0 | 2 | 1 | | T. | 0 | T. | 2 | T. | T. | 2 | T. | 1 | 2 | T. | | T. | T. | T. | 2 | 2 | T. | 1 |
| 1927 | 3 | T. | 3 | T. | 0 | 0 | 0 | 0 | 5 | T. | 0 | T. | 1 | T. | 7 | 1 | | T. | T. | 3 | 6 | 5 | 1 | 2 |
| Average | 2 | T. | 2 | T. | 0 | T. | 0 | T. | 2 | T. | T. | 1 | 1 | T. | 5 | T. | | T. | T. | 1 | 3 | 4 | T. | 1 |

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TABLE 8.—*Stem-rust coefficients on 23 varieties of oats grown in different sections of the United States and eastern Canada during one or more of the five years from 1923 to 1927*—Continued

[T.=Trace]

| Area and year | Coefficients of infection | | | | | | | | | | | | | | | | | | | | | | Severity of rust epidemic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avena sativa | | | | | | | | | | | | | | | | A. sativa orientalis | | A. byzantina | | | | |
| | Early | | | | | | | | Midseason | | | | | | | | Late | | Early | | | Midseason | |
| | White | | | | Yellow | | | | Gray | White | | | | Yellow | | Black | White | | Red | | | Red | |
| | Gopher | Iowa No. 444 | Iowar | "Rustless selection" | Edkin | Hajira | Iogold | Richland | Ruakura | Anthony | Minota × White Tartar (White Russian) | Silvermine | Swedish Select | Logren | Markton | Joanette | Green Mountain | White Tartar | Burt | Fulghum | Kanota | Red Rustproof | |
| Southern States: | | | | | | | | | | | | | | | | | | | | | | | |
| 1923 | | | 13 | 11 | | | | 0 | 15 | | | 15 | 7 | 13 | | | | T. | | 10 | | 15 | 10 |
| 1924 | | | 6 | 4 | | 4 | | 8 | 6 | | | 7 | 7 | 8 | | 5 | 4 | 2 | 1 | 2 | | 5 | 5 |
| 1925 | | | T. | 0 | | 0 | | T. | 1 | T. | T. | 1 | 4 | 3 | | T. | | 0 | T. | 1 | 3 | 1 | 1 |
| 1926 | 10 | 5 | 12 | 12 | | T. | T. | 6 | 14 | 2 | 1 | 21 | 20 | 20 | 7 | 10 | | 2 | 6 | 17 | 9 | 6 | 21 | 10 |
| 1927 | 4 | 4 | 4 | 2 | 1 | T. | T. | 2 | 7 | T. | T. | 6 | 5 | 8 | 5 | 1 | | T. | T. | 6 | 5 | 6 | 5 | 3 |
| Average | 6 | 4 | 6 | 5 | 1 | T. | T. | 3 | 7 | 1 | T. | 9 | 9 | 10 | 6 | 3 | 4 | 1 | 2 | 7 | 6 | 6 | 9 | 5 |
| North-Central and Northeastern States: | | | | | | | | | | | | | | | | | | | | | | | |
| 1923 | | | 9 | 5 | | | | T. | 19 | | | 12 | 16 | 12 | | 15 | | | T. | | 12 | | 17 | 11 |
| 1924 | | | 11 | 7 | | T. | | T. | 22 | | | 28 | 19 | 25 | | 9 | 10 | | T. | 11 | 17 | | 27 | 14 |
| 1925 | | | 14 | 16 | | 1 | | 1 | 37 | 2 | 3 | 34 | 32 | 32 | | 17 | | 2 | 2 | 28 | 30 | | 39 | 18 |
| 1926 | 32 | 13 | 30 | 28 | | 2 | 1 | 2 | 51 | 3 | 3 | 54 | 45 | 48 | 56 | 31 | | 3 | 4 | 29 | 40 | 50 | 59 | 28 |
| 1927 | 32 | 15 | 34 | 23 | 3 | 3 | T. | T. | 43 | 5 | 4 | 53 | 56 | 51 | 54 | 24 | | 5 | 4 | 28 | 39 | 37 | 56 | 26 |
| Average | 32 | 14 | 20 | 16 | 3 | 1 | 1 | 1 | 35 | 4 | 3 | 37 | 35 | 35 | 55 | 19 | 19 | 3 | 2 | 25 | 29 | 43 | 40 | 21 |
| Eastern Canada: | | | | | | | | | | | | | | | | | | | | | | | |
| 1925 | | | T. | 1 | | 0 | | T. | 2 | | | 8 | 5 | 7 | | 2 | | T. | T. | 3 | 3 | | 5 | 3 |
| 1926 | 30 | 3 | 17 | 20 | | 1 | T. | T. | 56 | 7 | 4 | 49 | 33 | 50 | 41 | 7 | | 6 | 4 | 24 | 42 | 41 | 23 | 22 |
| Average | 30 | 3 | 9 | 11 | | T. | T. | T. | 31 | 7 | 4 | 30 | 21 | 31 | 41 | 4 | | 4 | 2 | 15 | 24 | 41 | 15 | 15 |
| General average | 18 | 8 | 12 | 10 | 3 | 1 | T. | 1 | 21 | 2 | 1 | 22 | 20 | 21 | 32 | 10 | 14 | 2 | 2 | 15 | 18 | 26 | 22 | 12 |

### FIVE-YEAR SUMMARY

Almost exactly a third of all the varieties, selections, and crosses tested in the nurseries from 1923 to 1927 proved highly resistant to stem rust under most conditions. Their average infection coefficients ranged from less than one-half of 1 per cent to a trifle higher than 3 per cent. In the descending order of their rust resistance these varieties are Iogold, Hajira, Richland, Minota × White Tartar (White Russian), White Tartar, Green Mountain, Anthony, and Edkin. Markton was the most susceptible variety of all, but it was grown only two years, and these were the heaviest stem-rust years of the 5-year period. Markton, however, did have the highest average infection coefficient and was consistently more heavily infected than any other variety. Moreover, when compared with Silvermine, a standard susceptible variety, its susceptibility ratio was the highest of all. (Tables 9 and 10, and fig. 3.)

In Table 9 is presented the frequency distribution, by classes, of the stem-rust infection coefficients. Five classes are recognized: (1) Very light, 0 to trace; (2) light, 1 to 10 per cent; (3) moderate, 11 to 30 per cent; (4) heavy, 31 to 60 per cent; and (5) very heavy, 61 to 100 per cent. Very light infection does not necessarily indicate inherent resistance on the part of a given variety. It often means simply a paucity of inoculum or an escape from infection due to environmental conditions rather than genetic factors for resistance. When the infection is heavy, the coefficient exceeding 31 per cent, there is likely to be some loss. When the infection is very heavy, over 61 per cent, the loss probably is considerable.

TABLE 9.—*Frequency distribution of stem-rust infection coefficients for 23 varieties of oats grown in uniform nurseries in the United States and eastern Canada during the five years from 1923 to 1927*

| Group and variety | Number and percentage of observations for degree of rust infection | | | | | | | | | | Nursery years | Average infection coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Very light (0 to trace) | | Light (1–10) | | Moderate (11–30) | | Heavy (31–60) | | Very heavy (61–100) | | | |
| | Number | Per cent | Number | Per cent | Number | Per cent | Number | Per cent | Number | Per cent | | |
| *Avena sativa* | | | | | | | | | | | | |
| Early white: | | | | | | | | | | | | |
| Gopher | 25 | 30.12 | 24 | 28.92 | 16 | 19.28 | 8 | 9.64 | 10 | 12.04 | 83 | 18.4 |
| Iowa No. 444 | 35 | 43.75 | 26 | 32.50 | 13 | 16.25 | 5 | 6.25 | 1 | 1.25 | 80 | 8.2 |
| Iowar | 65 | 38.01 | 58 | 33.92 | 27 | 15.79 | 14 | 8.19 | 7 | 4.09 | 171 | 11.6 |
| "Rustless selection" | 66 | 38.15 | 62 | 35.84 | 31 | 17.92 | 8 | 4.62 | 6 | 3.47 | 173 | 10.2 |
| Early yellow: | | | | | | | | | | | | |
| Edkin | 37 | 78.72 | 5 | 10.64 | 3 | 6.38 | 2 | 4.26 | | | 47 | 3.2 |
| Hajira | 128 | 84.77 | 21 | 13.91 | | | 2 | 1.32 | | | 151 | .9 |
| Iogold | 68 | 86.08 | 11 | 13.92 | | | | | | | 79 | .4 |
| Richland | 154 | 89.54 | 14 | 8.14 | 2 | 1.16 | 1 | .58 | 1 | .58 | 172 | 1.2 |
| Early gray: | | | | | | | | | | | | |
| Ruakura | 51 | 29.65 | 37 | 21.51 | 36 | 20.93 | 30 | 17.44 | 18 | 10.47 | 172 | 21.1 |
| Midseason white: | | | | | | | | | | | | |
| Anthony | 83 | 64.84 | 38 | 29.69 | 5 | 3.91 | 2 | 1.56 | | | 128 | 2.1 |
| Minota × White Tartar (White Russian) | 95 | 74.22 | 28 | 21.88 | 5 | 3.90 | | | | | 128 | 1.4 |
| Silvermine | 55 | 31.61 | 44 | 25.29 | 29 | 16.67 | 24 | 13.79 | 22 | 12.64 | 174 | 21.5 |
| Swedish Select | 58 | 33.33 | 39 | 22.41 | 33 | 18.97 | 25 | 14.37 | 19 | 10.92 | 174 | 19.8 |
| Midseason yellow: | | | | | | | | | | | | |
| Iogren | 55 | 31.79 | 32 | 18.50 | 38 | 21.97 | 29 | 16.76 | 19 | 10.98 | 173 | 21.1 |
| Markton | 18 | 21.95 | 17 | 20.73 | 12 | 14.64 | 15 | 18.29 | 20 | 24.39 | 82 | 31.8 |
| Midseason black: | | | | | | | | | | | | |
| Joanette | 68 | 39.76 | 50 | 29.24 | 35 | 20.47 | 14 | 8.19 | 4 | 2.34 | 171 | 10.2 |
| Monarch Selection (of Etheridge) | 4 | 21.05 | 7 | 36.84 | 5 | 26.32 | 3 | 15.79 | | | 19 | 13.5 |

TABLE 9.—*Frequency distribution of stem-rust infection coefficients for 23 varieties of oats grown in uniform nurseries in the United States and eastern Canada during the five years from 1923 to 1927*—Continued

| Group and variety | Number and percentage of observations for degree of rust infection | | | | | | | | | | Nursery years | Average infection coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Very light (0 to trace) | | Light (1–10) | | Moderate (11–30) | | Heavy (31–60) | | Very heavy (61–100) | | | |
| | Number | Per cent | Number | Per cent | Number | Per cent | Number | Per cent | Number | Per cent | | |
| *A. sativa orientalis* | | | | | | | | | | | | |
| Late white: | | | | | | | | | | | | |
| Green Mountain | 91 | 67.91 | 35 | 26.12 | 7 | 5.22 | 1 | .75 | ------ | ------ | 134 | 1.9 |
| White Tartar | 118 | 67.82 | 49 | 28.16 | 6 | 3.45 | 1 | .57 | ------ | ------ | 174 | 1.7 |
| *A. byzantina* | | | | | | | | | | | | |
| Early red: | | | | | | | | | | | | |
| Burt | 57 | 37.50 | 31 | 20.39 | 33 | 21.71 | 24 | 15.79 | 7 | 4.61 | 152 | 14.9 |
| Fulghum | 52 | 30.23 | 44 | 25.58 | 37 | 21.51 | 26 | 15.12 | 13 | 7.56 | 172 | 17.8 |
| Kanota | 18 | 21.95 | 19 | 23.17 | 22 | 26.83 | 10 | 12.20 | 13 | 15.85 | 82 | 25.6 |
| Midseason red: | | | | | | | | | | | | |
| Red Rustproof | 58 | 33.53 | 35 | 20.23 | 33 | 19.08 | 19 | 10.98 | 28 | 16.18 | 173 | 21.8 |
| Total number and average percentage | 1,459 | 47.62 | 726 | 23.69 | 428 | 13.97 | 263 | 8.58 | 188 | 6.14 | 3,064 | 12.3 |

From Table 9 it will be seen that there seldom was more than light infection on any of the eight resistant varieties. Iogold never showed more than a light infection, while the remaining seven varieties, except Edkin, developed an infection heavier than light in approximately 1 to 6 per cent of the observations. On Edkin 6.38 per cent of the observations were recorded as moderate and 4.26 per cent as heavy. Not a single case of very heavy infection has thus far been noted on this strain of oats. Even the most susceptible varieties sometimes escape infection. As a matter of fact, 20 per cent of the observations showed a trace, or less, of stem rust on at least some of the varieties. But on the seven most susceptible varieties—Kanota, Silvermine, Iogren, Ruakura, Red Rustproof, Markton, and Swedish Select—there was heavy to very heavy infection in about 25 to somewhat less than 43 per cent of the observations. Of these varieties, Markton had the highest percentage (42.68) and Swedish Select the lowest (25.29). Markton, furthermore, had the highest percentage of very heavy infections, namely, 24.39. Next in order was Red Rustproof, with 16.18 per cent. Kanota, with 15.85 per cent, followed very closely.

Table 10 summarizes the stem-rust data by years and gives weighted averages for all varieties during the entire 5-year period. A comparison of these with that of Silvermine for the same period of nursery years also is given. The last two features are illustrated graphically in Figure 3, the varieties being arranged in the order of their relative susceptibility, with Silvermine as the standard of comparison.

TABLE 10.—*Average coefficient of stem-rust infection on varieties of oats grown in uniform nurseries at 65 experiment stations in the United States and eastern Canada during one or more of the five years from 1923 to 1927*

[The comparison of the infection coefficient with that of Silvermine oats for the corresponding period is expressed as a percentage ratio]

| Group and variety | C. I. No. | Nursery years | Coefficients of infection | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Annual average | | | | | 5-year average | | |
| | | | 1923 | 1924 | 1925 | 1926 | 1927 | Weighted average for variety | Silvermine for same period | Percentage of Silvermine |
| *Avena sativa* | | | | | | | | | | |
| Early white: | | | | | | | | | | |
| Gopher | 2027 | 83 | ------ | ------ | ------ | 19.3 | 17.8 | 18.4 | 28.5 | 64.56 |
| Iowa No. 444 | 2331 | 80 | ------ | ------ | ------ | 7.2 | 8.9 | 8.2 | 29.2 | 28.08 |
| Iowar | 847 | 171 | 9.0 | 8.2 | 4.7 | 16.1 | 17.3 | 11.6 | 21.1 | 54.98 |
| "Rustless selection" | 724 | 173 | 5.9 | 5.5 | 5.3 | 15.8 | 14.3 | 10.2 | 21.3 | 47.89 |
| Early yellow: | | | | | | | | | | |
| Edkin | 2330 | 47 | ------ | ------ | ------ | ------ | 3.2 | 3.2 | 26.4 | 12.12 |
| Hajira | 1001 | 151 | ------ | .7 | .2 | .7 | 1.9 | .9 | 22.8 | 3.95 |
| Iogold | 2329 | 79 | ------ | ------ | ------ | .6 | .2 | .4 | 28.7 | 1.39 |
| Richland | 787 | 172 | .1 | .9 | .4 | 2.4 | 1.6 | 1.2 | 21.0 | 5.71 |
| Early gray: | | | | | | | | | | |
| Ruakura | 2025 | 172 | 16.0 | 17.1 | 13.1 | 31.1 | 24.5 | 21.1 | 21.0 | 100.48 |
| Midseason white: | | | | | | | | | | |
| Anthony | 2143 | 128 | ------ | ------ | .9 | 2.2 | 3.0 | 2.1 | 23.7 | 8.86 |
| Minota × White Tartar | 2144 | 128 | ------ | ------ | 1.2 | 2.0 | 1.4 | 1.4 | 23.7 | 5.91 |
| Silvermine | 659 | 174 | 11.4 | 19.4 | 12.4 | 31.2 | 27.3 | 21.5 | 21.5 | 100 |
| Swedish Select | 134 | 174 | 13.0 | 13.7 | 12.2 | 26.1 | 27.2 | 19.8 | 21.5 | 92.09 |
| Midseason yellow: | | | | | | | | | | |
| Iogren | 2024 | 173 | 12.2 | 17.2 | 12.0 | 30.7 | 27.6 | 21.1 | 21.3 | 99.06 |
| Markton | 2053 | 82 | ------ | ------ | ------ | 31.6 | 31.9 | 31.8 | 28.5 | 111.58 |
| Midseason black: | | | | | | | | | | |
| Joanette | 1880–1 | 171 | 13.2 | 5.7 | 5.8 | 14.2 | 11.7 | 10.2 | 21.6 | 47.22 |
| Monarch Selection (of Etheridge) | 1879 | 19 | ------ | 13.5 | ------ | ------ | ------ | 13.5 | 19.4 | 69.59 |
| *A. sativa orientalis* | | | | | | | | | | |
| Late white: | | | | | | | | | | |
| Green Mountain | 1892 | 134 | ------ | ------ | .6 | 2.5 | 2.7 | 1.9 | 23.3 | 8.16 |
| White Tartar | 551 | 174 | .3 | .5 | .7 | 3.5 | 2.3 | 1.7 | 21.5 | 7.91 |
| *A. byzantina* | | | | | | | | | | |
| Early red: | | | | | | | | | | |
| Burt | 2043 | 152 | ------ | 9.8 | 10.1 | 18.9 | 18.1 | 14.9 | 22.5 | 66.22 |
| Fulghum | 708 | 172 | 12.1 | 12.9 | 11.3 | 23.9 | 23.7 | 17.8 | 20.9 | 85.17 |
| Kanota | 839 | 82 | ------ | ------ | ------ | 28.8 | 22.2 | 25.6 | 28.0 | 91.43 |
| Midseason red: | | | | | | | | | | |
| Red Rustproof | 1815 | 173 | 15.0 | 19.4 | 13.8 | 28.5 | 28.1 | 21.8 | 21.2 | 102.83 |
| Average severity of epidemic | ------ | ------ | 9.8 | 10.4 | 6.6 | 16.1 | 14.4 | 12.3 | 21.5 | 57.23 |

## PUCCINIA CORONATA AVENAE

Systematic observations on crown-rust infection in the uniform oat nurseries were first made in 1925. Notes on crown rust and stem rust can not be taken to best advantage at the same time. Most of the nurseries were visited by the rust observers only once during a season at a time most favorable for taking notes on stem rust. As a result, the number of nurseries from which crown-rust data are available is smaller than that from which stem-rust data were obtained. For reasons given previously, infection coefficients were not calculated for crown rust. Infection readings are given in percentages. The

results obtained each year are presented in Tables 11 to 13. Table 14 is a summary of the 3-year period. Figure 4 compares the weighted 3-year average infection of the different varieties with that of White Tartar.

### CROWN-RUST SITUATION BY YEARS

In 1925 there was little crown rust in the territory as a whole. None whatever could be found in the nurseries in the Great Plains

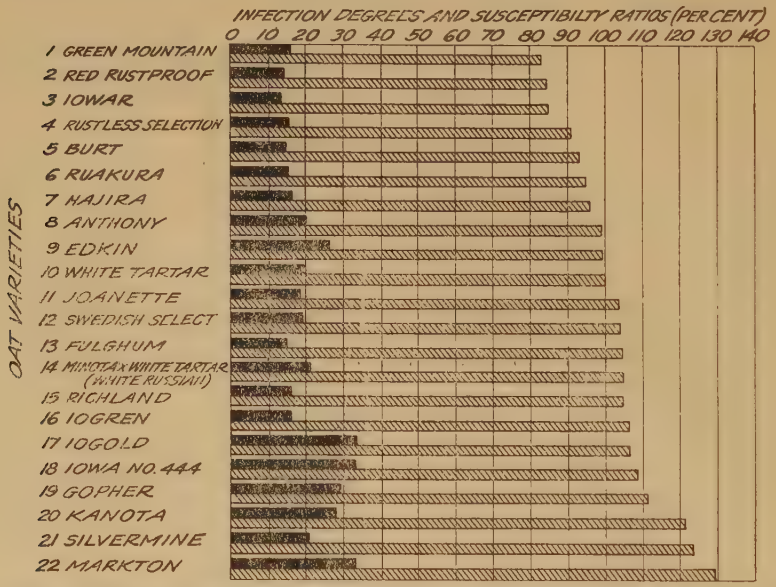


FIGURE 4.—Diagram illustrating the weighted average percentages of infection (solid black) and the relative degree of susceptibility (hatching) of varieties of oats grown in uniform crown-rust nurseries during one or more of the three years 1925, 1926, and 1927. (Numbers preceding names of varieties indicate order of relative degree of susceptibility)

area, very little in those in the Southern States, and only a moderate epidemic in the nursery at Morris, Minn. At Fargo, N. Dak., and Ottawa, Ontario, the epidemic was somewhat heavier but not destructive. In the nursery at Madison, Wis., however, crown-rust infection was very heavy, affecting all the varieties except Ruakura and Red Rustproof. Data for 1925 are given in Table 11.

TABLE 11.—*Percentage of crown rust on 16 varieties of oats grown in uniform nurseries at 31 experiment stations in the United States and eastern Canada in 1925*

[T.=Trace]

| Location | Estimated percentage of infection | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avena sativa | | | | | | | | | | | A. sativa orientalis | | A. byzantina | |
| | Early | | | | | Midseason | | | | | | Late | | Early | Midseason |
| | White | | Yellow | | Gray | White | | | | Yellow | Black | White | | Red | Red |
| | Iowar | "Rustless selection" | Hajira | Richland | Ruakura | Anthony | Minota × White Tartar (White Russian) | Silvermine | Swedish Select | Iogren | Joanette | Green Mountain | White Tartar | Burt | Fulghum | Red Rustproof |
| Northern Great Plains: | | | | | | | | | | | | | | | |
| Archer, Wyo. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fort Collins, Colo. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| North Platte, Nebr. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Southern Great Plains: | | | | | | | | | | | | | | | |
| Colby, Kans. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hays, Kans. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Woodward, Okla. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Balmorhea, Tex. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Southern States: | | | | | | | | | | | | | | | |
| Denton, Tex. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Temple, Tex. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Starkville, Miss. | T. | T. | T. | T. | 30 | T. | T. | T. | T. | T. | 10 | T. | 25 | T. | T. | T. |
| Columbus, Kans. | 0 | 0 | 0 | 0 | T. | 0 | 0 | T. | 0 | 0 | 0 | 0 | 0 | T. | 0 | 0 |
| Manhattan, Kans. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Columbia, Mo. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | T. | 0 | 0 | T. | 0 | 0 | 0 | 0 | 0 |
| Vincennes, Ind. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Murfreesboro, Tenn. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lexington, Ky. | 0 | T. | T. | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 5 | T. | T. | T. | 0 | 0 |
| Experiment, Ga. | T. | T. | T. | 0 | ------ | 0 | 0 | 0 | T. | T. | T. | T. | T. | 0 | 0 | T. |
| Athens, Ga. | ---- | ---- | ---- | ---- | T. | T. | T. | ---- | T. | T. | T. | T. | T. | ---- | ---- | T. |
| Knoxville, Tenn. | 0 | 0 | 0 | 0 | T. | 0 | 0 | 0 | 0 | 0 | T. | T. | T. | 0 | 0 | 0 |
| North-Central States: | | | | | | | | | | | | | | | |
| Lincoln, Nebr. | 0 | T. | T. | 0 | 0 | 0 | 0 | 0 | T. | 0 | 0 | T. | 0 | 0 | 0 | 0 |
| Brookings, S. Dak. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | T. | 0 | 0 | 0 |
| Fargo, N. Dak. | 7 | 13 | 30 | 8 | 12 | 55 | 30 | 35 | 28 | 5 | 42 | 15 | 43 | 12 | 10 | 3 |
| Morris, Minn. | 10 | 7 | 3 | 15 | 13 | 13 | 25 | 28 | 18 | 15 | 30 | 23 | 3 | 7 | 8 | 10 |
| Madison, Wis. | 65 | 85 | 90 | 75 | T. | 100 | 100 | 95 | 100 | 95 | 100 | 100 | 100 | 70 | 85 | T. |
| Gurnee, Ill. | 5 | 1 | 1 | 5 | 0 | 2 | 3 | 1 | 5 | 1 | 5 | 2 | 5 | 2 | 1 | 0 |
| Chatham, Mich. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| La Fayette, Ind. | 0 | 0 | 0 | T. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Eastern Canada: | | | | | | | | | | | | | | | |
| Guelph, Ontario | T. | T. | T. | T. | T. | ---- | ---- | T. | T. | 7 | T. | T. | T. | T. | 0 | T. |
| Ottawa, Ontario | 30 | 25 | 15 | 25 | 0 | ---- | ---- | 50 | 25 | 45 | 35 | T. | 20 | 35 | T. | 0 |
| Kentville, Nova Scotia | T. | 0 | 0 | T. | 0 | ---- | ---- | T. | 7 | T. | T. | 0 | T. | 0 | 0 | 0 |
| Charlottetown, Prince Edward Island | T. | T. | T. | T. | 0 | ---- | ---- | 35 | T. | 25 | T. | 0 | T. | T. | 0 | 0 |
| Average infection | 4 | 4 | 5 | 4 | 2 | 6 | 6 | 8 | 6 | 6 | 7 | 5 | 6 | 4 | 3 | T. |

There was considerably more crown rust in the nurseries in 1926 than in 1925, averaging more than 24 per cent in 1926 as compared with less than 5 per cent the previous year. In 1926 crown rust was extremely heavy at Baton Rouge, La., and at College Station, Tex. At Baton Rouge 100 per cent infection was recorded for every one of the 21 varieties grown there that year. At College Station the estimated percentage ranged from 75 to 100 on the 17 varieties on which the crown-rust observations were made. The epidemic was not quite so severe at Denton and Temple, Tex., and only a trace of crown rust was found at Chillicothe, Tex. The epidemic was uniform and fairly

heavy at Starkville, Miss. At Tifton, Ga., it was rather uniform, but only moderate in intensity. No crown rust was found at Jackson, Tenn., with the exception of 12 per cent on Iowa No. 444. The nurseries at Lexington, Ky., and Blacksburg, Va., were entirely free from crown rust. There was rather heavy infection on a number of the varieties at Ottawa, but considerably less at Guelph, Ontario. At St. Anne de la Pocatière, Quebec, and at Fredericton, New Brunswick, not more than a trace of crown rust appeared on any of the varieties. However, at Charlottetown, Prince Edward Island, 12 per cent of crown rust was recorded on Iowa No. 444. At this station two varieties, Hajira and Red Rustproof, were entirely free from crown rust, while all varieties other than Iowa No. 444 had only a trace. From 20 to 40 per cent of crown rust appeared on three of the varieties in the Kentville, Nova Scotia, nursery. Data are presented in Table 12.

TABLE 12.—*Percentage of crown rust on 21 varieties of oats grown in uniform nurseries at 16 experiment stations in the United States and eastern Canada in 1926*

[T.=Trace]

| Location | Estimated percentage of infection | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avena sativa | | | | | | | | | | | | | | | A. sativa orientalis | A. byzantina | | | | | |
| | Early | | | | | | | Midseason | | | | | | | | Late | Early | | | | Midseason | |
| | White | | | | Yellow | | | Gray | White | | | | Yellow | | Black | White | Red | | | | Red | |
| | Gopher | Iowa No. 444 | Iowar | "Rustless selection" | Hajira | Iogold | Richland | Rivakura | Anthony | Minota × White Tartar (White Russian) | Silvermine | Swedish Select | Iogren | Markton | Joanette | Green Mountain | White Tartar | Burt | Fulghum | Kanota | Red Rustproof | |
| Southern Great Plains: | | | | | | | | | | | | | | | | | | | | | | |
| Chillicothe, Tex. | --- | --- | T. | T. | T. | --- | T. | T. | T. | T. | T. | T. | T. | --- | T. | T. | T. | T. | T. | --- | T. | |
| Southern States: | | | | | | | | | | | | | | | | | | | | | | |
| Denton, Tex. | --- | --- | 20 | 35 | 35 | --- | 70 | 10 | 70 | 65 | 50 | 60 | 25 | --- | 70 | 75 | 70 | 50 | 70 | --- | 65 | |
| Temple, Tex. | --- | --- | 10 | 25 | 15 | --- | 50 | 40 | 8 | 15 | 28 | 25 | 30 | --- | 20 | 15 | 0 | 30 | 20 | --- | 32 | |
| College Station, Tex. | 90 | 75 | 90 | 100 | 100 | 100 | 90 | --- | 75 | 100 | 90 | 90 | 100 | --- | 75 | 75 | 100 | 90 | --- | --- | 100 | |
| Baton Rouge, La. | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | |
| Starkville, Miss. | 53 | --- | 45 | 55 | 43 | --- | 58 | 58 | 50 | 58 | 58 | 53 | 45 | 75 | 40 | 45 | 63 | 45 | 45 | 45 | 58 | |
| Jackson, Tenn. | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Lexington, Ky. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tifton, Ga. | 35 | --- | 15 | 23 | 25 | --- | 35 | 25 | 15 | 10 | 25 | 15 | 25 | 45 | 25 | 10 | 25 | 25 | 15 | 35 | 25 | |
| Blacksburg, Va. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Eastern Canada: | | | | | | | | | | | | | | | | | | | | | | |
| Guelph, Ontario | T. | --- | T. | 3 | T. | --- | T. | 25 | 30 | 30 | 25 | T. | 25 | T. | 30 | 10 | 20 | 10 | 3 | 5 | T. | |
| Ottawa, Ontario | 63 | 50 | 35 | 40 | 60 | 60 | 55 | 10 | 45 | 45 | 70 | 63 | 55 | 75 | 15 | 35 | 35 | 50 | 30 | 7 | 5 | |
| St. Anne de la Pocatière, Quebec | T. | 0 | T. | 0 | T. | T. | T. | 0 | 0 | T. | T. | T. | 0 | 0 | 0 | 0 | 0 | T. | T. | 0 | 0 | |
| Fredericton, New Brunswick | T. | T. | 0 | 0 | 0 | T. | 0 | 0 | T. | T. | 0 | T. | 0 | T. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Kentville, Nova Scotia | 0 | 40 | 0 | 20 | 0 | 0 | 0 | T. | 0 | 38 | T. | T. | T. | 0 | T. | T. | 0 | 0 | 0 | 0 | T. | |
| Charlottetown, Prince Edward Island | T. | 12 | T. | T. | 0 | T. | T. | T. | T | T. | T. | T. | T. | T. | T. | T. | T. | T. | T. | T. | 0 | |
| Average infection | 26 | 29 | 20 | 25 | 24 | 26 | 29 | 18 | 25 | 29 | 28 | 25 | 25 | 25 | 24 | 23 | 26 | 25 | 19 | 16 | 24 | |

TABLE 13.—*Percentage of crown rust on 22 varieties of oats grown in uniform nurseries at 14 experiment stations in the United States in 1927*

[T.=Trace]

| Location | Estimated percentage of infection | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avena sativa | | | | | | | | | | | | | | | | A. sativa orientalis | | A. byzantina | | | |
| | Early | | | | | | | | | Midseason | | | | | | | Late | | Early | | | Midseason |
| | White | | | | Yellow | | | | Gray | White | | | | Yellow | | Black | White | | Red | | | Red |
| | Gopher | Iowa No. 444 | Iowar | "Rustless selection" | Edkin | Hajira | Iogold | Richland | Ruakura | Anthony | Minota × White Tartar (White Russian) | Silvermine | Swedish Select | Iogren | Markton | Joanette | Green Mountain | White Tartar | Burt | Fulghum | Kanota | Red Rustproof |
| Northern Great Plains: | | | | | | | | | | | | | | | | | | | | | | |
| Webster, S. Dak. | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 15 | 15 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 15 | 25 | 30 | 30 | 40 | 15 |
| Redfield, S. Dak. | 35 | 10 | 40 | 20 | 40 | 15 | 10 | 30 | 25 | 10 | 25 | 80 | 15 | 15 | 25 | 25 | 5 | 15 | 20 | 60 | 10 | 15 |
| Highmore, S. Dak. | 10 | 20 | 15 | 10 | 25 | 40 | 20 | 40 | 30 | 20 | 15 | 25 | 25 | 65 | 10 | 40 | 2 | 2 | 10 | 10 | 25 | 15 |
| Archer, Wyo. | T. | T. | T. | T. | T. | T. | T. | T. | T. | T. | T. | T. | T. | T. | T. | T. | 0 | 0 | T. | T. | T. | T. |
| Southern Great Plains: | | | | | | | | | | | | | | | | | | | | | | |
| Colby, Kans. | T. | 0 | T. | T. | T. | T. | 0 | T. | T. | 0 | 0 | T. | T. | T. | T. | T. | T. | T. | T. | --- | T. | T. |
| Southern States: | | | | | | | | | | | | | | | | | | | | | | |
| Starkville, Miss. | 40 | 40 | 15 | 15 | 45 | 25 | 30 | 30 | 75 | 25 | 40 | 40 | 25 | 40 | 50 | 40 | 40 | 25 | 5 | 75 | 95 | 50 |
| Jackson, Tenn. | 60 | 25 | 75 | 40 | 50 | 75 | 40 | 50 | 85 | 60 | 60 | 75 | 100 | 60 | 95 | 40 | 25 | 65 | 55 | 75 | 75 | 75 |
| Manhattan, Kans. | 90 | 90 | 90 | 70 | 90 | 70 | 90 | 90 | 90 | 90 | 80 | 90 | 70 | 90 | 90 | 80 | 70 | 90 | 90 | 90 | 70 | 90 |
| Auburn, Ala. | 5 | T. | 10 | 5 | 5 | 5 | T. | 5 | 15 | T. | 3 | 5 | 10 | 5 | 20 | 20 | 15 | 5 | 3 | 15 | 40 | 25 |
| North-Central States: | | | | | | | | | | | | | | | | | | | | | | |
| Fargo, N. Dak. | --- | --- | --- | --- | --- | --- | 100 | --- | 100 | 100 | 100 | --- | 100 | --- | --- | 100 | 100 | 100 | --- | --- | --- | --- |
| Crookston, Minn. | --- | 100 | --- | 90 | --- | 85 | --- | --- | --- | 90 | 90 | 90 | 90 | --- | 75 | 90 | 90 | 85 | --- | --- | --- | 80 |
| Waseca, Minn. | 85 | 65 | 50 | 75 | T. | 75 | 90 | 80 | 85 | 50 | 50 | 80 | 65 | 60 | 90 | 50 | 10 | 50 | 85 | 80 | 80 | 60 |
| Chatham, Mich. | --- | 100 | --- | --- | --- | --- | 100 | --- | --- | 100 | 100 | --- | --- | --- | --- | --- | 100 | 100 | --- | --- | --- | --- |
| Columbus, Ohio | 10 | 5 | --- | 10 | 5 | 10 | 10 | 10 | 10 | 15 | 5 | 5 | 10 | 5 | 20 | 10 | 3 | 10 | 10 | 10 | 15 | 2 |
| Average infection | 33 | 37 | 32 | 30 | 26 | 35 | 40 | 32 | 44 | 42 | 42 | 43 | 41 | 33 | 42 | 40 | 34 | 41 | 28 | 45 | 41 | 36 |

Crown rust was far heavier in 1927 than in any of the other years under review, as is shown by the data presented in Table 13. The average infection for the year was over 37 per cent. The only places with only a trace or none were Archer, Wyo., and Colby, Kans. The infection at Auburn, Ala., and Columbus, Ohio, was rather light, but at the other 11 experiment stations where estimates could be made, some or all of the varieties were severely injured. The damaging effect of crown rust could be observed in many more places than those indicated in Table 13, but because of the lateness of the season no percentage estimates could be made. At Manhattan, Kans., all of the varieties were heavily infected, as was true of the varieties on which crown-rust estimates could be made at Fargo, N. Dak., Crookston, Minn., and Chatham, Mich. At Starkville, Miss., Burt was the most resistant of the varieties; at Redfield, S. Dak., Green Mountain was most resistant. At Highmore, S. Dak., Green Mountain and White Tartar were most resistant. At Waseca, Minn., Edkin

was much more resistant than Green Mountain. At the remaining stations there were no striking differences in the susceptibility of the different varieties. On the average, Edkin and Burt appeared to be the most resistant varieties in 1927, while Fulghum and Ruakura had the highest average infection. In 1926 Ruakura and Fulghum were among the three most resistant varieties, and Burt was on the average much more susceptible. It seems probable, therefore, that different physiologic forms of *Puccinia coronata avenae* were primarily responsible for the rust in the two years.

### THREE-YEAR SUMMARY

Evidently there was a difference in the distribution of the physiologic forms of crown rust in the different nurseries during each of the three years 1925, 1926, and 1927. It is obviously difficult, however, to determine from the field results alone the exact identity of the form or forms present at a given place. In 1925 there was a very severe epidemic of crown rust at Madison, Wis. (Table 11.) All of the varieties except Ruakura and Red Rustproof developed from 65 to 100 per cent of rust. On these two only a trace of rust was found. Judging from Parson's (*16*) analytical key, either form 3 or form 5, or possibly both, were present. At Ottawa, Ontario, from 15 to 50 per cent of crown rust was recorded in 1925 on all but four varieties. Among these, Ruakura and Red Rustproof were entirely free from rust, while Fulghum and Green Mountain had only a trace. It seems likely that the crown-rust epidemic at Ottawa in 1925 was caused by a physiologic form hitherto undescribed, for until then Fulghum had proved susceptible to all known forms of crown rust. The identity of this form could be established definitely, however, only by additional studies not included within the scope of these investigations. In 1926, varietal reactions indicated that *Puccinia coronata avenae* form 1 was the most prevalent form, whereas in 1927 other forms, among them form 2, were present in several nurseries. Other forms undoubtedly were present, but their identity could not be determined from field observations alone.

Form 1, which has a wide host range, evidently was equally widespread and abundant. As may be seen from Table 14 and Figure 4, the average infection for all of the varieties for the 3-year period 1925 to 1927 was 18.8 per cent, the lowest for any one variety (Iowar) being 13.5 per cent, and the highest (Iogold) 33.7 per cent. The spread between the varieties least affected and those most affected was slightly over 20 per cent. In other words, the crown-rust effect on Iogold on the average was almost exactly two and one-half times as great as that on Iowar. However, when all the varieties are grouped on the basis of relative resistance at all stations with White Tartar as the standard variety, Green Mountain was least susceptible and Markton was most so. Designating White Tartar, a relatively susceptible variety, as 100 per cent susceptible, the susceptibility ratio of Green Mountain was 82.97 per cent and that of Markton 129.69 per cent. The interval between the two extremes is seen to be comparatively small. This was not true, however, for stem rust. Markton, the variety most heavily infected with stem rust, had an average infection coefficient almost eighty times as great as that of Iogold, the variety with the lightest infection, the susceptibility ratios being 111.58 per cent for the former and 1.39 for the latter. Markton had the highest susceptibility ratio for both rusts.

TABLE 14.—*Average degree of crown-rust infection on varieties of oats grown in uniform nurseries at 46 experiment stations in the United States and eastern Canada during one or more of the three years 1925, 1926, and 1927*

[The comparison of the infection percentage with that of White Tartar oats for the corresponding period is expressed as a percentage ratio]

| Group and variety | C. I. No. | Nursery years | Percentage of infection | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Annual average | | | 3-year average | | |
| | | | 1925 | 1926 | 1927 | Weighted average for variety | White Tartar for same period | Percentage of White Tartar |
| *Avena sativa* | | | | | | | | |
| Early white: | | | | | | | | |
| Gopher | 2027 | 24 | ------ | 26.3 | 32.7 | 29.3 | 26.3 | 111.41 |
| Iowa No. 444 | 2331 | 23 | ------ | 28.9 | 36.9 | 33.4 | 30.7 | 108.79 |
| Iowar | 847 | 56 | 3.9 | 19.8 | 32.0 | 13.5 | 15.9 | 84.91 |
| "Rustless selection" | 724 | 58 | 4.4 | 25.1 | 30.0 | 15.4 | 16.9 | 91.12 |
| Early yellow: | | | | | | | | |
| Edkin | 2330 | 11 | ------ | ------ | 26.0 | 26.0 | 26.1 | 99.62 |
| Hajira | 1001 | 58 | 4.7 | 23.7 | 35.4 | 16.3 | 16.9 | 96.45 |
| Iogold | 2329 | 23 | ------ | 26.1 | 39.6 | 33.7 | 31.4 | 107.32 |
| Richland | 787 | 57 | 4.3 | 28.7 | 31.8 | 16.5 | 15.8 | 104.43 |
| Early gray: | | | | | | | | |
| Ruakura | 2025 | 57 | 1.9 | 17.9 | 44.2 | 15.0 | 15.8 | 94.94 |
| Midseason white: | | | | | | | | |
| Anthony | 2143 | 57 | 6.3 | 24.6 | 41.8 | 20.2 | 20.4 | 99.02 |
| Minota × White Tartar | 2144 | 57 | 5.9 | 28.9 | 42.4 | 21.3 | 20.4 | 104.42 |
| Silvermine | 659 | 58 | 8.2 | 27.7 | 42.9 | 20.8 | 16.9 | 123.08 |
| Swedish Select | 134 | 60 | 5.9 | 25.4 | 41.2 | 18.8 | 18.1 | 103.87 |
| Midseason yellow: | | | | | | | | |
| Iogren | 2024 | 58 | 6.3 | 25.4 | 33.2 | 16.6 | 15.5 | 107.10 |
| Markton | 2053 | 24 | ------ | 24.7 | 41.7 | 33.2 | 25.6 | 129.69 |
| Midseason black: | | | | | | | | |
| Joanette | 1880–1 | 60 | 7.4 | 23.5 | 40.0 | 18.7 | 18.1 | 103.31 |
| *A. sativa orientalis* | | | | | | | | |
| Late white: | | | | | | | | |
| Green Mountain | 1892 | 61 | 4.6 | 22.9 | 33.9 | 16.1 | 19.4 | 82.99 |
| White Tartar | 551 | 61 | 6.4 | 25.8 | 40.9 | 19.4 | 19.4 | 100 |
| *A. byzantina* | | | | | | | | |
| Early red: | | | | | | | | |
| Burt | 2043 | 57 | 4.2 | 25.1 | 28.0 | 14.7 | 15.8 | 93.04 |
| Fulghum | 708 | 55 | 3.5 | 18.9 | 44.5 | 15.1 | 14.5 | 104.14 |
| Kanota | 839 | 23 | ------ | 16.0 | 40.9 | 27.9 | 23.0 | 121.30 |
| Midseason red: | | | | | | | | |
| Red Rustproof | 1815 | 58 | .5 | 24.1 | 35.6 | 14.3 | 16.9 | 84.61 |
| Average severity of epidemic | ------ | ------ | 4.9 | 24.3 | 37.2 | 18.8 | 19.4 | 96.91 |

## DESCRIPTION OF VARIETIES

Brief notes on the origin, description, distribution, and economic importance of the rust-resistant and commercially important oat varieties included in the various uniform nurseries are here given. Some of the varieties have been described more fully elsewhere, in which cases references are given. Furthermore, most of them have been registered either as standard or improved varieties and strains by the American Society of Agronomy in cooperation with the Bureau of Plant Industry.

Iowar, Iogren, Iogold, Iowa No. 444, Richland (Iowa No. 105), and "Rustless selection" (C. I. Nos. 847, 2024, 2329, 2331, 787, and 724, respectively) were developed by the Iowa Agricultural Experiment Station, in cooperation with the Office of Cereal Crops and Dis-

eases, Bureau of Plant Industry. The origin, description, and distribution of Iowar, Iogren, and Richland have been reported by Burnett, Stanton, and Warburton (*4*) and by Stanton, Griffee, and Etheridge (*20*). Similar information on Iogold recently has been published by Burnett (*3*) and by Stanton, Love, and Gaines (*22*).

"Rustless selection" and Iowa No. 444 have not been previously described. Nursery records show that the original "rustless" oat was grown by the Iowa Agricultural Experiment Station at Ames as early as 1904. According to L. C. Burnett, of that station, it was among the varieties and strains included in the original cooperative nursery grown at Ames in 1906. "Rustless" was grown in nursery row No. 23. At harvest the plants were pulled and kept separate for each row. Those selected from row 23 were given Iowa numbers 427 to 447, inclusive. After some years of testing all these selections were discarded except No. 444, which has been continued in the experiment at Ames under the designation "Rustless selection." It is a white, rather small-kerneled oat, ripening a little later than Iowar but earlier than Silvermine.

The second strain of "rustless" oats, which was included in the uniform nurseries for the first time in the spring of 1926 as Iowa No. 444 (C. I. No. 2331), also was obtained from the Iowa Agricultural Experiment Station, where it was originated several years ago as a reselection of the original "Rustless selection," described above. This strain is similar to "Rustless selection" in plant and kernel characters. Neither of these strains as yet has been distributed to farmers.

Edkin (C. I. No. 2330) is a selection from the original Kherson variety (C. I. No. 459), made at Akron, Colo., in 1921 by F. A. Coffman. Edkin is a high-yielding, typical yellow-kerneled Kherson strain. Its high resistance to stem rust was first noted at Ames, Iowa, during the severe epidemic of 1926. Edkin is of considerable promise agronomically.

Gopher (C. I. No. 2027; Minn. No. 674), a white-kerneled selection from Sixty-Day, was developed and distributed by the Minnesota Agricultural Experiment Station. Brief statements on the history and general description of Gopher have been published by Stanton, Griffee, and Etheridge (*20*), and by the Minnesota Agricultural Experiment Station (*14*). It is now an important commercial variety in Minnesota.

Hajira (C. I. No. 1001) was introduced through the Office of Foreign Plant Introduction, Bureau of Plant Industry. The record is as follows (*24*):

> 48089. From Johannesburg, Transvaal. Purchased from the Agricultural Supply Association, through Mr. J. Burtt Davy, botanist. Received September 24, 1919. Quoted note by Mr. Davy. "*Heijira* rustproof oats. A rather recent introduction which has been grown with some success in the dry districts of the Western Transvaal and is claimed to be rust resistant."

In a letter dated July 2, 1928, H. S. du Toit, Chief of the Division of Agricultural Education and Extension, Department of Agriculture, Pretoria, Union of South Africa, supplied additional information on the origin of Hajira as follows:

> I beg to inform you that in 1904 I obtained a small parcel of seed from Hajira or El-Hajira, a city in Algeria. The variety was unknown to me and had apparently no particular name, so I simply named it after the place where I got it from.

In another letter dated July 6, 1928, W. G. Stahl, senior research officer, Division of Field and Animal Husbandry, Department of Agriculture, Union of South Africa, states that Colonel du Toit, after introducing the Hajira oat, subsequently grew it at Lichtenburg and in Western Transvaal and then distributed it to various other semi-arid parts of what now constitutes the Union of South Africa. He mentions that since its introduction the name Hajira has become corrupted and is variously spelled Heijara, Hajera, and Heijira.

Hajira, or Heigira, as it has been wrongly spelled in this country, is an early, midtall, yellow-kerneled oat. It has a rather weak straw. It matures at about the same time as Richland, Iogold, and Kherson, and has shown only fair yielding ability. Because of its early maturity and high resistance to stem rust, Hajira is of some economic promise.

The Ruakura oat, also known as Ruakura Rust-Resistant, originated at the Ruakura Farm of Instruction in New Zealand as a plant variation in the Red Algerian (Argentine) variety. The variety has been described by Archer (*1*). Several introductions of the variety have been made. The particular strain of Ruakura (C. I. No. 2025) used in the experiments reported herein was introduced by the Ohio State University. This strain is somewhat more uniform in kernel characters than the earlier introductions and, for this reason, was used in the uniform nurseries. Ruakura is an early oat with equilateral panicles and a fine, rather weak straw. The kernels are grayish in color. In some spikelets the second floret separates from the first similarly to those of the Red Algerian variety. On this account there has been some doubt regarding its classification as belonging to *Avena sativa* L. The variety is of little commercial promise in the United States.

The development of the Markton variety (C. I. No. 2053) has been described by Stanton, Stephens, and Gaines (*23*) and by Stanton, Griffee, and Etheridge (*20*). Markton was included in the rust nurseries because of its immunity from the smuts of oats. It is of considerable commercial importance in Oregon, Washington, Idaho, and adjacent Montana, where the rusts of oats have not been a serious limiting factor in yield.

Anthony (C. I. No. 2143; Minn. No. 686) and Minota × White Tartar (White Russian) (C. I. No. 2144; Minn. No. 687) were bred by the Minnesota Agricultural Experiment Station (*14*). Anthony resulted from a cross between Victory and White Tartar (White Russian). Both of these productions are midseason sorts with white kernels. Anthony is being increased for distribution to farmers.

Silvermine, Swedish Select, White Tartar (White Russian), Green Mountain, Joanette, and Monarch Selection (C. I. Nos. 659, 134, 551, 1892, 1880–1, and 1879, respectively) have been described by Etheridge (*8*). The Silvermine and Swedish Select are widely distributed standard midseason white oats. The introduction of Swedish Select has been described by Carleton (*5*). Both White Tartar and Green Mountain are late varieties with side panicles. The latter differs from the former only in having awns. The resistance of White Tartar to stem rust has been recognized in the United States for 40 years or more. These so-called "side oats" have not attained great economic importance, however, owing to their late maturity and low yielding power. White Tartar has persisted in

sections only where stem rust frequently is a limiting factor in production. Joanette and Monarch Selection are black-kerneled sorts. Joanette is grown commercially to some extent in Canada, but is of little agricultural importance in the United States. Monarch Selection has been grown only at experiment stations.

Burt, Fulghum, Kanota, and Red Rustproof (C. I. Nos. 2043, 708, 839, and 1815, respectively) differ from all the other varieties previously discussed in that they belong to the red-oat group, *Avena byzantina* C. Koch. Burt (C. I. No. 2043) is a selection from a hybrid between two strains of Burt made by Jesse B. Norton in 1902 at the Arlington Experiment Farm, Rosslyn, Va. This strain has been included for several years in the varietal experiments at the Iowa Agricultural Experiment Station, Ames, Iowa, where it has been among the best of numerous Burt strains. It is typical of the variety in plant and kernel characters.

The history and description of the Fulghum variety has been published by Stanton (*19*). Salmon and Parker (*17*) and Stanton, Love, and Down (*21*) have reported on the development and performance of Kanota, a strain of Fulghum which has become of great economic importance.

The Red Rustproof strain (C. I. No. 1815) used in these experiments was obtained from the Georgia State College of Agriculture, Athens, Ga., by the Office of Cereal Crops and Diseases in 1920 under the name Appler. It is a typical strain of the well-known Red Rustproof (Red Texas) oat of the South. The variety has been described by Etheridge (*8*), Warburton and Stanton (*25*), and others.

## GENERAL DISCUSSION

In the studies herein reported several varieties of oats proved generally resistant to stem rust. Iogold, Hajira, Richland, Minota × White Tartar (White Russian), White Tartar, Green Mountain, and Anthony were the most resistant of all. The fact that these varieties were so universally resistant, while many others were so universally susceptible, indicates that the very virulent physiologic forms of *Puccinia graminis avenae* which are known to occur in other countries are not abundant and widespread in the United States, although there is evidence that they may be present. This conclusion is supported by observations in the uniform rust nurseries and also by inoculations in the greenhouse, compared with rust collections from the nurseries and elsewhere.

In 1923 only physiologic forms 1 and 2 of *Puccinia graminis avenae* were identified with certainty, although there was good evidence that a collection made by Wallace Butler on December 28, 1923, at West, Tex., contained a virulent form not hitherto found. White Tartar and Green Mountain had been moderately resistant and Richland and Hajira highly resistant to all collections made in the summer and fall. However, the collection made by Butler produced two types of uredinia on the same leaf of Richland, minute uredinia in necrotic areas, and large, normal uredinia as well. The rust from the large uredinia was propagated and was virulent on all varieties inoculated. Unfortunately, however, seed of "Joanette Strain" and "Strain 703" was not available for the tests, and it was therefore impossible to distinguish this culture from form 4. As the large uredinia had appeared on only

one plant of Richland and form 4 had been cultured in the same greenhouse previously, it was suspected that the large uredinia might have resulted from accidental infection. In the light of subsequent events, however, it seems more likely that the rust actually had been present in the field. Repeated attempts to again isolate the virulent form were unsuccessful.

In the following year, 1924, all winter and spring oat varieties in the nursery at Temple, Tex., were infected with stem rust. This indicated the presence of some exceptionally virulent physiologic form, possibly *Puccinia graminis avenae* form 6, hitherto unknown on this continent or elsewhere. The rust notes on the Temple material were not taken in the field as usual, but the almost-mature plants were harvested and shipped to St. Paul, Minn., for examination. The notes were taken by A. W. Henry and the senior writers of this bulletin. It was very difficult to obtain a culture from this material, for, in most cases, the rust was in the telial stage, and most of the urediniospores were nonviable. Finally, after a number of attempts, a culture was obtained from the rust on Silvermine. Both White Tartar and Richland proved resistant, however. Evidently, if a very virulent form of stem rust occurred at Temple in 1924, other less virulent forms also were present that year.

In 1925 between 40 and 50 specimens of *Puccinia graminis avenae* were collected and cultured at St. Paul. Of 32 collections determined, 29 (approximately 91 per cent) were form 2; the remaining 3 cultures were of form 1. It was in this year that the presence of the very virulent form of *P. graminis avenae* was first definitely discovered in Canada. This form may possibly have been present at West, Tex., in 1923 and at Temple, Tex., in 1924.

There was considerable stem rust on White Tartar and Richland at College Station, Tex., in 1926, and its development on both varieties seemed normal. On Hajira there was very little stem rust, however. This is circumstantial evidence of the presence of two forms identical with, or similar to, forms 3 and 4. These forms were not isolated, however, from the specimen collected at the College Station nursery; instead, forms 1 and 2 were isolated. Possibly the host from which the isolation was made harbored forms 1 and 2 but not form 3 or 4. There was, then, circumstantial evidence of the presence in the southern United States of forms which can attack some of the resistant varieties, but the case was not proved.

In 1927 more than 100 identifications of stem rust of oats were made. As in previous years, form 2 was most prevalent, and form 5 was the only other form isolated. Although a very careful study was made of all collections obtained, it could not be demonstrated definitely that the virulent European forms and the form more recently found in Canada exist in the United States. The circumstantial evidence presented in this bulletin and the greenhouse and field studies of other investigators (*15*, *7*) seem to indicate the occurrence of these forms in the United States. Positive experimental proof, however, is still lacking.

If the very virulent forms of *Puccinia graminis avenae* do not spread into the United States, the development of good varieties of oats resistant to stem rust seems well on the way toward realization. Garber (*9*) developed Anthony (*14*), a cross between Victory and White Tartar, which combines the desirable characters of the first

parent and the stem-rust resistance of the second. Burnett (*3*) previously had selected Iogold from Kherson. Iogold is even more resistant to stem rust than Anthony, is high yielding, and has stiff straw. No variety has yet proved resistant to the apparently omnivorous form 6. Should form 6 become established in this country, as it has in Canada, and become widespread the development of rust-resistant varieties will become much more difficult. Its eventual appearance in the United States seems inevitable.

Although several varieties of oats were extremely resistant to stem rust under field conditions, no variety approached a like degree of resistance to crown rust. The variety showing the lowest percentage of crown-rust infection during 56 nursery years, Iowar, had a susceptibility quotient 33.75 times greater than the variety with the lowest average stem-rust coefficient for 79 nursery years, Iogold. There was not so great a range in the susceptibility of different varieties to crown rust as there was in the susceptibility of stem rust. Nevertheless, Green Mountain, Red Rustproof, Iowar, "Rustless selection," Burt, Ruakura, and Hajira were somewhat more resistant than the other varieties. It was evident from field observations that physiologic specialization in *Puccinia coronata avenae* complicates the situation.

There was no apparent correlation between resistance to stem rust and resistance to crown rust. While of all varieties Iogold was the most resistant to stem rust, it was among the most susceptible to crown rust. Red Rustproof was next to the most susceptible to stem rust, but the second most resistant to crown rust. On the other hand, one or two varieties that were highly resistant to stem rust also were among the most resistant to crown rust. As already stated, Markton was the most susceptible to both rusts. A cursory examination of Figures 3 and 4 reveals the lack of correlation in resistance to the two rusts. Careful greenhouse tests have not yet shown any positive correlation in any of the small grains between the resistance to stem rust and leaf rust.

Observations also were made on the degree of smut in the different varieties grown in the nurseries. While complete notes were taken only in 1925, estimates of the percentage of both smuts were made virtually every year. As these observations were only incidental, the seed was not inoculated artificially; hence nothing is known about the number of physiologic forms which may have caused the infection. As the seed was grown at Aberdeen, Idaho, it is probable that it was infected with only the forms present at that place. The results, therefore, are not necessarily indicative of the behavior of these varieties toward smut in commercial fields in other regions. Under the conditions of these experiments, however, the following varieties were very resistant to both smuts: Markton, Red Rustproof, Fulghum, and Hajira. The following were moderately resistant: Burt, Richland, Silvermine, "Rustless selection," and Iowar. The following were moderately susceptible: Iogren, Joanette, Minota × White Tartar, Ruakura, and Swedish Select; and those extremely susceptible were White Tartar, Green Mountain, and Anthony.

Unfortunately, there appears to be no correlation whatever between smut resistance and resistance to the rusts. For example, Markton and Fulghum were very resistant to both smuts, but extremely sus-

ceptible both to stem rust and crown rust. Red Rustproof also was highly resistant to both smuts and also to crown rust, but was very susceptible to stem rust. On the other hand, Green Mountain was susceptible to both smuts, but resistant to both rusts; and Anthony was very susceptible to the smuts and to crown rust, but resistant to stem rust. Again, Ruakura was very susceptible to the smuts and to stem rust, but resistant to crown rust. Hajira was the only variety which appeared to be resistant to both smuts and both rusts.

The smuts can be prevented by seed treatment, but it would be highly desirable to combine rust resistance and smut resistance in one variety, if possible. To do this probably will necessitate a detailed study of the number, distribution, and constancy of the physiologic forms of the smut fungi as well as the rusts. The results presented emphasize the fact that there is not necessarily any correlation in the resistance of varieties of oats to different diseases.

## SUMMARY

A uniform nursery experiment was started in 1923 to determine under field conditions in different areas the relative resistance of varieties of oats to *Puccinia graminis avenae* and to determine the distribution of physiologic forms of the pathogene in the experimental territory. Beginning with 1925, observations were made on crown rust.

At first only 11 varieties of oats were grown at 21 experiment stations. Eventually 22 varieties were studied at 48 stations. Altogether, during the five years 1923 to 1927, 23 varieties were tested at as many as 65 different experiment stations.

The percentage of stem rust usually was estimated before the plants ripened; crown-rust notes were taken when the leaves were still green. The rust scale of the Office of Cereal Crops and Diseases, Bureau of Plant Industry, was used as a basis for the estimates. In the case of stem rust, in addition to the estimates of infection, notes were taken on the nature of host reaction. A numerical value was assigned to the latter, and by multiplying it by the estimated percentage an infection coefficient was obtained. The latter seemed a more accurate expression of the effect of stem rust on the host plants than a mere percentage figure. The percentage reading, however, was thought to be adequate to represent susceptibility to crown rust.

There was a very pronounced difference in the quantity and quality of the stem-rust infection on different varieties at different stations in different years. The following eight varieties, selections, and crosses were most resistant to stem rust during the period under review: Iogold, Hajira, Richland, Minota × White Tartar (White Russian), White Tartar, Green Mountain, Anthony, and Edkin. The average infection coefficients for these varieties ranged from less than 0.5 per cent to a little over 3 per cent. In comparison with a standard variety grown during the same period, the extreme susceptibility ratios were 1.39 and 12.12 per cent, respectively.

The differences in the effects of crown rust on the different varieties were not so striking as those of stem rust. The spread between the least affected and most affected varieties was slightly more than 20 per cent in the case of crown rust and almost 31.5 per cent in the case of stem rust. Even more striking is the difference in the relative sus-

ceptibility ratios of the most resistant and most susceptible varieties to crown rust and stem rust, respectively. For crown rust, the lowest and highest ratios were 82.97 and 129.69 per cent and for stem rust 1.39 and 111.58 per cent. The six varieties least affected by crown rust were Green Mountain, Red Rustproof, Iowar, "Rustless selection," Burt, and Ruakura.

In general there seemed to be no correlation in varietal resistance between the two rusts. Some of the varieties most resistant to stem rust were among those most susceptible to crown rust, and vice versa. Markton oats, however, was the most susceptible to both rusts.

Stem-rust specimens were collected each year from the different uniform nurseries and their identity determined by inoculations in the greenhouse at University Farm, St. Paul, Minn. Altogether, 121 collections from the nurseries were studied. Physiologic forms 1, 2, and 5 were isolated in the different years. Form 2 was by far the most prevalent. None of the extremely virulent forms known to occur abroad and in Canada has been isolated with certainty from the collections made in the United States, although there is considerable circumstantial evidence that they are present in this country.

Unless the above-mentioned virulent forms appear in the United States, the problem of developing good varieties of oats resistant to stem rust apparently is well on the way to solution. Such varieties as Iogold and Anthony, developed in Iowa and Minnesota, respectively, are outstanding in resistance to stem rust, in yielding ability, and other desirable characters. To be of greatest economic value, resistance to crown rust and smuts must be added.

Surveys of physiologic forms should be continued as a basis for breeding. Losses in the yield of oats due to stem rust are less severe now than they have been, owing in part at least to the progress made in eradicating barberries, but the program of breeding varieties resistant to both rusts must be continued if losses from these diseases are to be reduced to a minimum. At the same time barberry and buckthorn bushes should be eradicated in order to reduce the amount of inoculum, to decrease the opportunities for the persistence of physiologic forms now in existence, and to reduce the possibility of the production of new physiologic forms by hybridization.

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## ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

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